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REQUISITE AMOUNT OF WATER FOR A PUBLIC SUPPLY.

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[*Read November* 11, 1903.]

The useless waste of water is a serious loss and expense in nearly every community having a public water supply.

If any possible good could be accomplished by it some show of defence might be advanced for the practice, but it seems to be a loss and evil in every way. It has been suggested that the sewers are benefited by this flow of water, but the advantage, if any, in that respect is more than offset by the need of greater capacity in the sewer channels. A very small percentage of this waste if applied in flushing the sewers would be greatly more useful. An effort is usually made, in designing and building sewers, to keep out the ground water, but clearly the ground water would serve fully as good a purpose as a cleansing medium as the waste from the water works, and an additional advantage would come from its admission in the lowering of the water table about the foundations and the cellars of the buildings.

A liberal use of water ought to be provided in every family to insure cleanliness and every sanitary advantage, and an abundant flow everywhere for such purposes, and a liberal supply for all other legitimate objects, should be classed as use; but beyond this the waste is, I think, an unmixed evil.

Of the volume of water ordinarily supplied to a distribution system, much the larger portion, often reaching two-thirds or more

of the amount supplied, is uselessly wasted, and only a smaller portion is applied to any beneficial purpose. Such a condition ought not to exist, and it would seem to be the duty of every person having a position of authority in relation to a public supply to endeavor to limit the expenditure to that which will secure useful results, and to check or stop the reckless waste of money which now prevails.

The essential conditions for limiting a supply of water to useful purposes may be stated as follows:

1. A tight distribution and service system.

2. A proper system of water rates, inducing the water takers to desire the use of meters and not be opponents of their use.

3. The measurement of all water drawn by takers and payment in proportion to volume. As an incident to this a determination of the supply required for various uses is desirable.

4. Watchfulness on the part of those in charge of the works to detect and remedy any abnormal conditions in the supply.

First. — Upon works already established, but little can be done to increase the tightness of the distribution and service systems except by repairs and renewals; but as very few systems are finished, the extensions may be made in a way to secure reasonably tight work. To this end the street mains should be made under proper specifications as to shapes and quality, and these should be enforced by proper and rigid inspection, at the foundry, by inspectors whose decisions cannot be warped in the interest of the pipe contractors. The shapes and dimensions of the bells and spigots are important elements in securing tight work. My experience leads me to the belief that as a rule the bells of water pipes are made too deep. In the city of Providence, where there are now about 340 miles of distribution pipes in service, and forming an extremely tight system, the bells are 2 inches deep for the 6-inch pipes and regularly increasing in depth to 4 inches for the 36-inch pipes (see Fig. 1). These straight pipes can be laid on sharper curves without affecting the tightness of the joint than would be possible with the deeper bells. These shallow bells have been in use on the system for about thirty-three years, and I believe no one having experience with them would be willing to use in their place the ordinary deeper bells. The specifications under which they are made require accurate work as to their form. In all

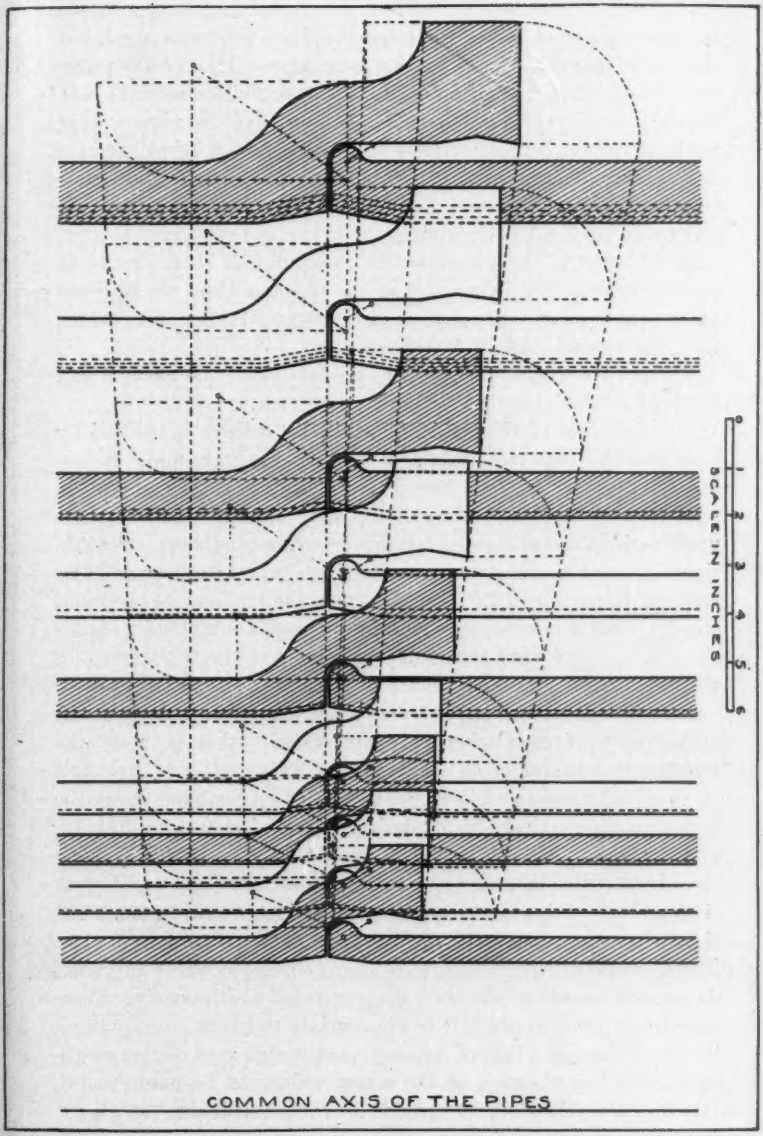


FIG. 1. PROVIDENCE PATTERN OF WATER-PIPE BELLS AND SPIGOTS.

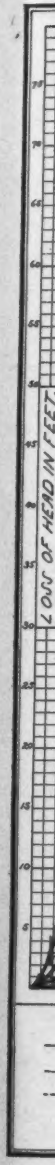
respects the specifications and inspection have been very rigid, but the city of Providence can buy its water pipes at the lowest prices notwithstanding the requirements. The foundries seem to seek the city's orders, for the reason possibly that they know that while they will be held strictly to the contract they will receive fair treatment from experienced men, and a certain foreknowledge of that fact outweighs any extra care their operatives are put to, to turn out perfect pipe.

In addition to the inspection at the foundries there should be careful and faithful inspection of the pipes as they are received at the pipe yard, especially to discover any faint cracks which may have developed in transportation

The proper widths and proper compacting of the gaskets and the lead in the joints is, of course, important.

The tightness of the service pipes in Providence is secured by requiring the best materials and the best workmanship. Before the mixture forming the bronze for making the taps and stops was determined upon, a large number of experiments was made upon various bronzes, and a mixture securing toughness, strength, tightness, and ease of working in the shops, so far as these could be combined, was selected. The work upon the tap, service pipe, and stop, forming a service, was done by the regular employees in the shop at the pipe yard of the department, and the tap was set in the street main, and the service pipe laid, by the department men.

Second. — The system of water rates should be based on the opportunity of each taker to waste water — that is, upon the number and character of the fixtures. This matter is discussed further under the third head. The size of service pipe should be based on the requirement for delivering useful water. A diagram giving the loss of head resulting from delivering certain quantities of water through the taps, service pipes, and stops of different sizes and for various lengths of pipe is a valuable aid in fixing the sizes of service pipes to be laid for takers. Such a diagram (Fig. 2) was made at the beginning of the delivery of water in Providence, and its value has been demonstrated continuously. Cases sometimes occur in which it is appropriate to insert a diaphragm in the tap having a hole of suitable size through it to deliver, without undue loss of head, all the water which can be made useful, but which would serve to throttle an excessive draft.



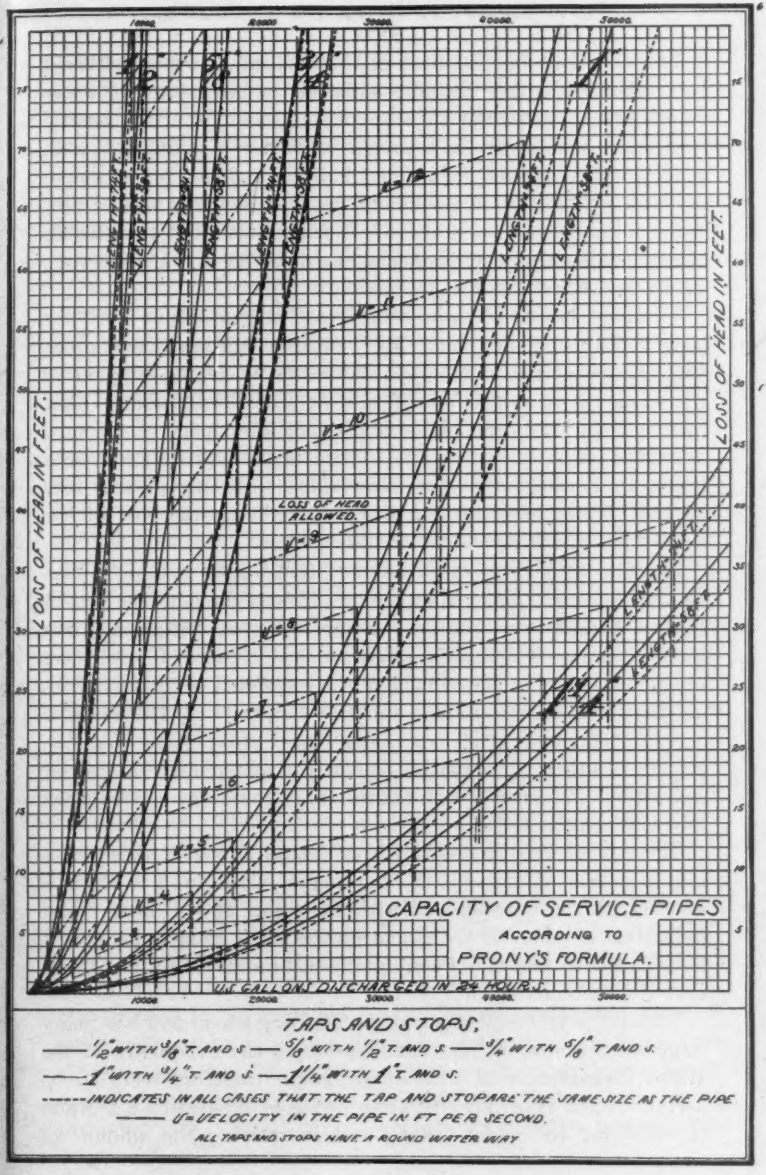

LOSS OF HEAD IN FEET.
LOSS OF HEAD ALLOWED.
CAPACITY OF SERVICE PIPES
ACCORDING TO
PRONY'S FORMULA.
TAPS AND STOPS.
1/2" WITH 3/8" T. AND S
5/8" WITH 1/2" T. AND S
3/4" WITH 5/8" T. AND S.
1" WITH 3/4" T. AND S
1 1/4" WITH 1" T. AND S.
INDICATES IN ALL CASES THAT THE TAP AND STOP ARE THE SAME SIZE AS THE PIPE.
V= VELOCITY IN THE PIPE IN FT. PER SECOND.
ALL TAPS AND STOPS HAVE A ROUND WATER WAY

FIG. 2.

Third. — The measurement of the amount of water delivered to a taker forms the only just basis for the payment of a water rate. The advantage of a system of water supply for the general protection against fire is a proper cause for a public tax, and, generally, this should yield about half the revenue for a system of water works. Other public and general uses may also be provided for by a tax upon the whole community, but the private consumer should pay according to the quantity of water he uses, with a proper provision for a minimum rate.

Excellent means of measurement are now available both for large and for small amounts. The Venturi meter has been of great value in measuring large supplies, whether in gaging supplies to the whole of, or to portions of, a system of distribution. Other meters of various forms, suitable and not too expensive, are now available for ordinary takers. There is therefore no sufficient objection, because of cost or uncertainty, to basing a water rate on the volume of water supplied, especially as the cost of the supply is largely dependent on the volume.

It seems to be popularly assumed that waste cannot be prevented, because it is not in human nature to submit to the sort of control necessary to limit the supply to useful purposes. But human nature does submit when properly treated, for we have several examples in New England of a contented community feeling that it has an abundant and free supply of all the water it cares to take and yet its per capita supply is far below that furnished to other communities similarly situated and of similar character. Whether human nature will submit, may depend upon how it is approached.

The city of Providence in Rhode Island is one of these communities that submits to the limiting of waste, and if there is another people more imbued with the rights of soul liberty and individual freedom to do as one pleases with what is his own I have failed to find it. Possibly the community may not know that it is submitting.

The city is preeminently a manufacturing place, and has many large users of water. An examination of the experience of the Water Department of Providence would therefore seem to be useful. I will take this city as an example illustrating a method of satisfying the water takers, and as showing the amount of

water required for a public supply. It seems to be appropriate also that I should do so because of my familiarity with the conditions obtaining in it. I was the designing and constructing engineer while the works were building, occupying a period of about seven years, during about five of which water was supplied to takers numbering at completion over a hundred thousand people. And after an interval of about thirteen years I again came into the department as city engineer for another period of seven years, at the end of which time the water takers numbered about one hundred and sixty-five thousand. My advice was followed in the beginning in fixing a basis or scheme according to which the revenue to be claimed from takers should be ascertained and controlled and economy of supply secured.

As a basis for determining the amount to be paid for water by takers, when it was not to be measured by meter, the opportunity to waste water was considered to be of the greatest importance. More water being wasted than used, the means of *wasting* water should govern the rental. This led to a schedule based upon the fixtures connected with the water pipes. Naturally the well-to-do, under this schedule, would pay more than the poor in proportion to the amount of water actually used, but a very important point was gained in the inducement offered to those who had many fixtures, to put in and maintain at their own expense meters for measuring the water taken by them. The water takers thus became the advocates of meters, and nearly all the meters on the works, numbering now nearly twenty thousand, or nearly 85 per cent. of all the services, have been applied at the request of the water takers. Possibly one quarter of one per cent. are exceptions, but probably the exceptions are less even than this small number.

When the rates were fixed the price for measured water was the common one, at that time in New England, of three cents per hundred gallons, and it was thought that ten dollars per year would pay, at that rate, for all the water that would be legitimately used by an ordinary family. It was important for sanitary reasons that no person should be restricted in the liberal use of water, and therefore a minimum rate was fixed so that no temptation should exist to lessen the real use of water, but only to prevent waste. The minimum charge of ten dollars per year was

therefore fixed for all who took *measured* water. That this was a fair estimate was proved by experience. Fifteen years after the delivery of water began about one half of all the families supplied by meter were paying the minimum rate, which entitled them to 91.32 gallons of water per family per day or, upon the basis of five persons per family, to 18.26 gallons per capita. It was noticed for many years that a large portion of the families supplied by meter did not draw more than about five dollars' worth per year. It is to be remembered that the poorer people are excluded from this list. They were generally supplied by one faucet at six dollars per year. It was only those who were supplied with extra fixtures for their convenience who had an object in paying for and maintaining a meter, and they could have no selfish incentive to save the water within the value of ten dollars per year. They used all they wanted, but they did not waste the water.

In 1888, seventeen years after the introduction of water, an analysis was made of the accounts of water takers through meters to determine the relative numbers of those using water within the minimum rate and also those using water amounting to other annual sums. Of those who were paying the minimum rate, I have examined the accounts of 2 553 families to learn the amounts of water drawn by each, and I have found that —

	Per annum.	*Gals. per day per tap*	*Which at 5 persons per family*
167 families drew less than	1 500 cu. ft.	=30.742	= 6.15 gals. per capita
237 families drew the previous amount but less than	2 000 cu. ft.	=40.989	= 8.20 gals. per capita
361 families drew the previous amount but less than	2 500 cu. ft.	=51.236	=10.25 gals. per capita
445 families drew the previous amount but less than	3 000 cu. ft.	=61.484	=12.30 gals. per capita
446 families drew the previous amount but less than	3 500 cu. ft.	=71.731	=14.35 gals. per capita
462 families drew the previous amount but less than	4 000 cu. ft.	=81.978	=16.40 gals. per capita

	Per annum.	*Gals. per day per tap*	*Which at 5 persons per family*
435 families drew the previous amount but less than	4 457 cu. ft.	=91.324	=18.27 gals. per capita

Twenty-five hundred and fifty-three families of a good class are thus shown to be using only from six to eighteen gallons of water per capita per day, and the number of families using even the least amount is too great to be put one side as abnormal. Some of the families using the smaller quantities are known to me to be liberal in all their ways of living and not economical to the extent of stinting themselves in any comfort or convenience. I think it is probable that the reason why some families use more than others is largely because of outside uses, like watering lawns, use in stables, greenhouses, etc., and because there are more members in the families. The amount of ground around the dwellings of Providence is unusually large. To illustrate the effect of outside uses on the quantity of water drawn I will instance the bills for eight successive years of the use of water at my own house, where the variation was almost solely caused by use on my large lawn. There were six to seven persons in the family, water in set fixtures on four floors, in modern conveniences, and a stable supplied through the house meter. The meter rate during this period was 2¼ mills per cubic foot, or 3 cents per 100 gallons. The amounts of the bills were —

1st year	$10.52	5th year	$18.36
2d „	47.21	6th „	18.05
3d „	28.25	7th „	17.87
4th „	56.50	8th „	14.59

This represents a per capita use for one year of say 80 gallons, and I suppose it was all used and not wasted, but it could hardly be classed as domestic or family use.

For an illustration of the relative number of meters passing different quantities of water for all uses, I will instance the analysis in Providence, in 1888, to which I have previously alluded. The number of meter accounts was 7 074, which are set out below in eleven classes.

Class.	*Number of accounts.*	*Amount of revenue received.*
Minimum charge ($10)	2 681	$26 810.00
$10 to $15	1 542	19 028.64
15 to 20	887	15 343.82
20 to 30	861	20 725.10
30 to 40	393	13 610.25
40 to 50	176	7 856.98
50 to 100	294	19 598.41
100 to 300	161	23 486.83
300 to 500	36	11 766.39
500 to 1 000	30	14 766.53
1 000 and excess	13	12 577.89
	7 074	$185 570.84

At the time this analysis was made, a sliding scale of discount was in operation as follows:

10%	discount on excess over	$50 to $100
20%	" " " "	100 " 300
30%	" " " "	300 " 500
40%	" " " "	500 " 1 000
50%	" " " "	1 000

This was afterwards changed to a uniform rate of 1½ mills per cubic foot, or 2 cents per 100 gallons, subject to a discount of 25 per cent. for amounts in excess of $600 per year in value. The accounts were classified according to the *gross* charge, and the *revenue* is given after the discount has been deducted, which accounts for the apparent discrepany in the statements under classification and those under revenue; for instance, the 13 accounts given as exceeding $1 000 amounted in gross to $20 085.80 and the sum of the discounts, at various stages, amounted to $7 507.91, which deducted leaves $12 577.89, the sum stated under revenue.

At the present time there are nearly twenty thousand meters in use, and of the rest of the services, say three thousand five hundred in number, all, probably, but about one per cent., are for supply to families using a single faucet, or two. The use of water from these services is satisfactory to the department, and it is believed from reports of the inspectors that no waste of consequence occurs.

Probably five sixths in number of all the services are used to supply families, and about half the services supply takers at the minimum meter rate or less, but there are very large takers on the system, and I believe that the proportion of the volume of water per capita used for other purposes than family use is greater

than in most of the other cities of the country. One taker, the railroad, draws about 450 000 gallons per day, a public institution draws about 250 000 gallons per day, and the electric light company draws about 200 000 gallons per day. There are fifty-two private takers who pay a water rate of more than a thousand dollars per year each. Of course these large takers run up the per capita use by the population very largely, and the influence of such takers must vary considerably between different cities. It must be instructive, however, to consider as a whole the experience of any large city which has succeeded in maintaining a moderate per capita use of water.

I give, in the table on the following page, some interesting facts in regard to the conditions, as a whole, in Providence, and will say that I believe an equally low per capita use might be secured in nearly every city of the country where such use is now exceeded, without permanently annoying its inhabitants and greatly to the advantage of such city in its tax rate or in its expense for maintaining water works, however its funds are raised for that purpose.

In the year 1892 the department noticed what was considered to be an unnecessary per capita use of water, and special inspectors were engaged to examine the supply through services, and the returns of the ordinary inspection were reviewed in the office to discover a reason for such use. About two years were occupied in the examination and in applying remedies. It was found that upon many of the unmetered services there was large waste, and the takers on such services were notified that under the provision in the published rates allowing special assessments to be made for peculiar circumstances they would be subjected to such special assessment, unless they chose to put on meters. A considerable number of such takers had meters set, and the rate of increase in the number of meters showed the influence of this move. The examination and the effort to check waste reached its culmination in 1894. In that year the average daily consumption of water was 9 904 434 gallons and the per capita supply was 65.24, which was larger than it had been before or has been since and undoubtedly more than was reasonable. The effect of the special effort to check waste was shown in the following year in two ways that were striking, when observed upon a profile illustrating the

conditions obtaining upon the work. *First:* The total average daily consumption of water dropped to 8 905 085 gallons and the per capita supply to 56.93 which was still fully up to the requirements for use. *Second:* The rate of increase in the revenue shot up in a marked way. The full effect of the effort to check waste was not, however, shown until 1897 when the total average daily

DISTRIBUTION, POPULATION AND PER CAPITA SUPPLY OF WATER IN PROVIDENCE, R. I.

Year.	*Miles of street mains.*	*Population supplied.*	*Miles of pipe per M. population.*	*Per capita supply of water.* (*Gallons.*)	*Percentage of services metered.*
1877	143.9212 ÷	102 900 =	1.3983	24.21	41.86
1878	149.0662 ÷	104 800 =	1.4224	25.79	43.16
1879	151.3890 ÷	106 875 =	1.4184	29.10	44.91
1880	154.5663 ÷	109 400 =	1.4128	32.42	46.62 Mar., '80
1881	159.4044 ÷	112 200 =	1.4207	33.13	47.65 Nov., '80
1882	166.7196 ÷	115 100 =	1.4485	31.85	No record
1883	176.6755 ÷	118 000 =	1.4973	35.12	52.38
1884	183.8386 ÷	120 900 =	1.5206	33.77	53.70
1885	189.3045 ÷	123 800 =	1.5291	38.21	55.45
1886	194.2298 ÷	126 700 =	1.5330	38.06	56.84
1887	203.3894 ÷	129 700 =	1.5681	38.08	58.06
1888	210.3669 ÷	132 600 =	1.5865	41.61	59.32
1889	218.0101 ÷	135 700 =	1.6066	42.64	60.61
1890	226.4792 ÷	138 700 =	1.6329	48.61	62.45
1891	243.5319 ÷	141 800 =	1.7174	51.28	63.42
1892	257.7153 ÷	144 900 =	1.7786	55.61	65.48
1893	273.2654 ÷	148 000 =	1.8464	63.30	69.40
1894	284.7603 ÷	151 800 =	1.8759	65.24	72.46
1895	296.2754 ÷	156 400 =	1.8943	56.93	74.58
1896	303.1921 ÷	162 200 =	1.8693	56.14	76.50
1897	310.3458 ÷	168 200 =	1.8451	51.34	78.42
1898	314.8528 ÷	174 200 =	1.8078	52.52	80.04
1899	318.4279 ÷	180 600 =	1.7631	52.94	81.46
1900	324.5557 ÷	186 800 =	1.7374	54.23	82.62
1901	331.0347 ÷	193 000 =	1.7152	55.62	83.58
1902	336.1560 ÷	199 400 =	1.6858	58.00	84.43

consumption of water had dropped to 8 635 067 gallons and the per capita supply to 51.34.

From that time to within about two years the increase in the total supply has been reasonably consistent with the increase of the population supplied.

Lately a new tendency is shown to dispose of a greater per

capita supply of water. This seems to be accounted for by the effect of electrolysis which has a destructive action in several places in the city. On one street several street mains have been taken out in two successive years, being badly decomposed and one of which had been completely eaten through. The iron bolts of meters have been eaten off and replaced by composition bolts. Lead service pipes have also been badly eaten. The conditions favoring the destructive action of electrolysis are being changed steadily for the better and it is hoped that the waste of water from this cause may be kept within reasonable limits.

It is believed there is a considerable waste in connection with the direct service to elevators from the pressure in the mains. One hundred and sixty-nine elevators are supplied in this way and the condition of their supply is now being examined.

The working force in the Meter Department in Providence consists of three men, who do all the setting and repairing of the meters on the system. The total expense of the department is more than returned to the city by the charges against the takers, they being at a fixed rate per meter for the usual operations. The average annual cost per meter for repairs is about eleven and one-half cents, the total cost for the last full year reported being $2 278.89.

Fourth. — Eternal vigilance is as necessary in a water department as in other matters, to secure a perfect result. It is found in Providence that there are men so lost to the dictates of a good conscience that they will tap in a supply back of the meter so as to draw water without having it measured.

Water is supplied to manufacturing establishments for fire purposes without cost when contained in pipes laid at the expense of the establishment and not connected with any other means of supply. It is a condition of such supply that no water whatever shall be drawn from these pipes except to extinguish fires. It was found at one time that about a million gallons per day extra was being drawn in a manufacturing section of the city and an inspector was sent out to locate the waste. It was found that two establishments near each other had opened their fire service pipes and were using the water for washing and other purposes. The fact that the combined use of the two was so great, facilitated the discovery.

Other surreptitious use of water has been discovered from time to time, like its use for broad irrigation, etc.

Nearly all the evils of waste can be cured by placing a meter on every service. It would hardly be expected in any community that illuminating gas would be furnished to takers except through a meter, notwithstanding the fact that gas is cheaper than water. In Providence gas is sold at $1.10 per thousand cubic feet while for water $1.50 per thousand cubic feet is paid.

DISCUSSION.

PRESIDENT WALKER. Well, gentlemen, that paper is a whole water works in itself. Does anybody want to make any remarks or ask any question? If so, please do so. Don't be afraid to ask the gentleman questions, he is able to answer them. I have been very much interested to notice that he seems to think that folks are not altogether honest in Providence, any more than they are in Manchester.

MR. H. G. HOLDEN. Mr. President, I would like to inquire of Mr. Shedd the amount and kind of lead used in a 2-inch bell.

MR. SHEDD. It is the ordinary soft lead that is used in laying water pipes, suitable, of course, for calking. It is laid a little more than three-quarters of an inch in depth, and the gasket makes up an inch or an inch and a quarter of the depth of the bell, and that is driven home until it will receive pretty good blows of a hammer without a depression in the gasket. I have found by a number of observations that it is almost impossible, in the ordinary lead used for making joints in water pipes, to have any apparent effect on the lead by any calking hammer more than three-quarters of an inch below the surface, as the lead seems to remain just as it is run, and it is not compacted in any degree below that depth, so far as I can discover, by the calking.

MR. HOLDEN. What amount of lead would be ordinarily used?

MR. SHEDD. Well, I do not carry that in my mind — it is less than the lead ordinarily used — but it is known. We have kept a very accurate account of the amount used in that way, and I have the figures, but I do not remember them. The amount of lead is carefully watched, of course, when the work is done by contract, and the inspector does not allow any less lead than the

specifications call for to go into the joints, but what the amount is, I do not remember.*

MR. GEORGE E. WINSLOW. Mr. President, I should like to ask Mr. Shedd in regard to the meters: Are they owned by the city or are they owned by the consumer?

MR. SHEDD. They are owned by the consumer, — by the water taker, but they are not allowed to be placed except by the city. The city approves of the meters, and sets them, and makes a charge for setting them to those who apply for them. The meter must be one which is approved by the city. There are three or four kinds of meters which are set by the city, and a person is allowed to make his choice from those kinds, but the meters are owned and maintained by the takers, so far as paying the money is concerned. They are managed by the city, put in by the city, repaired by the city, and the cost charged to takers for expenses.

MR. WINSLOW. What is the life of a meter, and under what conditions are they replaced?

MR. SHEDD. They are replaced at the expense of the taker, but the life of a meter — well, we have had some of them in there over thirty years, and apparently they are just as good as ever. There are meters there which were set at the beginning, and very few have failed; and this eleven cents I spoke of covers the maintenance.

MR. V. C. HASTINGS. How often, Mr. Shedd, do you test a meter?

MR. SHEDD. As often as there appears to be any reason for it. From the amount of water that is passed through, which is always observed when the inspector reads the meter at intervals of six months, it is discovered whether the meter runs freely or not.

* The calculated maximum width of lead joint and the weight, for each diameter of pipe, is as follows:—

Diam. of Pipe. (Inches.)	*Width of Joint. (Inches.)*	*Weight. (Pounds.)*	*Diam. of Pipe. (Inches.)*	*Width of Joint. (Inches.)*	*Weight. (Pounds.)*
4	1⅛	3.31	20	1⅞	21.14
6	1⅛	4.73	24	2	28.33
8	1¼	6.53	30	2¼	37.32
10	1⅜	8.56	36	2½	50.45
12	1⅜	10.84	48	3	105.83
16	1⅝	15.85			

MR. HASTINGS. I suppose if a man gets a big bill he would naturally want his meter tested?

MR. SHEDD. He naturally would. I got a notice yesterday of a big supply of water upon my house.

MR. EDWIN C. BROOKS. I would say, bearing upon the depth of bells, that we recently took out some water pipes in Cambridge which were laid in 1857, and the depth of bells in the Scotch pipe, cast in 9-foot lengths, was 7 inches (see Fig. 3). Quite a difference between that and 2 inches.

MR. JOHN C. CHASE. Mr. President, I should like to ask Mr. Shedd, if in estimating population between census years he

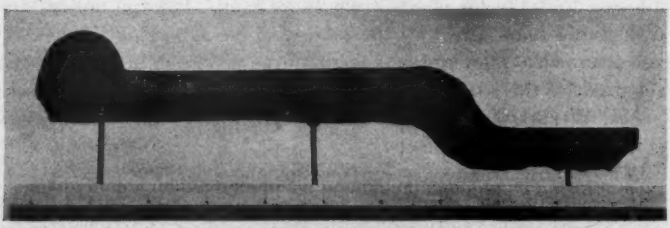


FIG. 3. SECTION OF BELL OF OLD WATER PIPE IN CAMBRIDGE.

added a certain per cent. for the growth of the population each year. If he can answer it, I should like to know what the additional per cent. was per year, and how it checked at the census periods?

MR. SHEDD. It came very close. We kept the population in a profile, going back as far as we had any population figures; and we have five-year periods of census taking; and every year the population is taken for the school census. When we have projected the line for five years, our projected line comes very close to the return actually found by the official census. The population given in my table runs from 102 900 in 1877 to 199 400 in 1902. That is not the population within the municipal limits, because we supply outside territory, and there are certain figures that we take from our own records.

MR. GEORGE F. CHACE. Mr. President: I should like to ask Mr. Shedd if he does not find it difficult with the shallow bells to get around curves.

MR. SHEDD. No. The possible turn of the pipe is greater,

without making a leaky joint, with the shallow bells than with the deep bells. You can see that if the deep bell pipe is turned, you don't have thickness enough for the lead joint on one side of the pipe. It is one of the chief advantages of the shallow bell that you can lay it with a greater curvature.

PRESIDENT WALKER. I want a bell from three and a half to four inches deep, to run around curves almost anywhere, but Mr. Shedd gets along with these short bells. I have been using three and a half inch to four inch bells, and I don't want to shift over, because there are a good many places where if I hadn't had a long bell I should have been up all night.

MR. SHEDD. We can show you three hundred and forty miles of short bells.

MR. CHARLES N. TAYLOR. My experience has been that I could get around a long curve with a long bell, as one edge of the spigot will be almost at the bell. I do not see that there is any disadvantage in having a long bell, but the thinner the lead, the stronger it is; that is my experience. I have had both kinds, and in order to lay around a sharp curve, I prefer a good-sized bell.

MR. ALBERT F. HILL. If I am going to have a pipe laid by contract, I want the bells a little longer than two inches. Unless the contract work is watched pretty closely, you will have a good many leaky joints with 2-inch bells. but they can be watched closely enough so you can get the joints tight. We have had a good many leaks where the work has been done by contract, if it was not inspected closely enough. If I lay the pipe myself I had as soon have a 2-inch bell as any other. I think a 3-inch bell is just about right.

MR. E. S. LARNED. As to the amount of water, of which we hear so much, and the remedies which are offered, it occurs to me that the majority of municipal engineers, or water-works engineers, are pretty well advised as to what is a requisite supply. While meters will bring to the minds of many people how much water they use there is a very large number in every wealthy community to whom it makes very little difference what the meter registers. Now, that is a class of waste which I think will in time demand very serious attention. It occurs to me that it might be a good thing, in order to determine what is a necessary and requisite supply, to fix a sliding scale, which will accordingly

result in increased revenue. It will draw attention of the people who insist on wasting water to the necessity of economizing.

MR. W. H. RICHARDS. Mr. President: I think the requisite supply varies with the place. That is, a city like Woonsocket, for instance, might have a very low per capita supply, being a manufacturing place, and where perhaps four or five families use one faucet, in some cases. Whereas, in another place, like Newton, for instance, where almost every family has a large number of fixtures, their per capita consumption would be naturally very much larger. So the per capita amount would depend on the city and on their method of using water. I think each place would have to be "a law unto itself."

As to the cost: The cost per thousand gallons of course varies in every city, and you would not want to get your meter rate below the cost of furnishing the water, certainly.

MR. R. C. P. COGGESHALL. Mr. President: I would like to ask Mr. Shedd if in his analysis of the Providence conditions he ever tried to account for all the water that was used, and if there was not quite a percentage that was apparently going to waste or that could not be accounted for. I know that Mr. Kieran of Fall River has for a number of years kept such an account, and while their per capita consumption is very low, still there is a large portion which he cannot account for, in spite of all the care that is taken to keep an accurate account of all the meters used. We all know that there is a certain leakage that is silently going on here and there in the ground, even under the best conditions. We know that in large manufacturing establishments, in large cotton plants, such as I have in my city, with meters on the pipes, there is a certain amount of water sliding away on Sundays. It it not very large, yet it amounts to a good deal in twenty-four hours. I don't know but Mr. Shedd has made some observations in that direction.

MR. SHEDD. It is unquestionably true that there is a loss of water in any distribution system and that it will be much less in some places than it is in others, depending upon the manner in which the distribution is made. Our consumption of water per capita is measured by the total amount of water pumped, and the quantity supplied by the pumps divided by the population supplied gives the per capita amount used, and that, of course, includes all the waste, the loss by leakage in distribution system.

MR. COGGESHALL. Then aside from the sum total of all the meters there is something left which you cannot account for?

MR. SHEDD. Yes; if we had 100 per cent. of our services metered, then perhaps we could.

MR. COGGESHALL. I believe that Mr. Robertson is here. Perhaps he will tell us something more definite about the Fall River supply.

MR. W. W. ROBERTSON. I did not come prepared, and memory is a very unreliable source of information in a meeting of this character. I can only speak in a general way, and say that for a number of years we have had a very systematic method, I think, of determining the amount of water used and the total pumpage accounted for. The houses are ninety or ninety-five per cent. on metered service, and for twenty or twenty-five years we have been increasing the number of meters. They are very popular in the city. They are purchased by the water takers, and there is no very great difficulty in inducing the water takers to take meters.

The rates were originally so high that in 1893 there was a sliding scale adopted by which there was a reduction of rates from 21 cents down to 7½. The reduction in rates is conducive to economy.

We had a great deal of waste from tank closets. That is the greatest source of waste we have had, but in later years we have paid attention to the waste problem and tried to regulate it. We put meters on our public buildings and found in that way how much water was used by the city departments. Every year we published a table showing the total of our investigations for that year, and the result is that we have supplied water quite economically.

At this time I cannot give you any figures. I can only refer you to our report and the table that has been contained in it from year to year for several years.

MR. COGGESHALL. I think at this point some of you will be interested to hear what Mr. Thomas has to say about what he has found out in regard to some corporations that have fire pipes, but do not use any water, — how much water is going through them.

MR. R. J. THOMAS. We have not found out how much water the corporations are using for fire service, because we haven't had meters, but the water board has determined to have meters

for fire service. There are about ten large corporations in the city that use the city supply as a secondary supply in the case of fire. When there are defective check valves it allows their water to pass into our mains, and we found it necessary for the health of the city to shut the valves on the branches that lead into the corporations, fifteen in all. Since shutting off these valves our consumption has fallen off from a quarter to half a million gallons a day.

That is all we know about it at the present time, but we expect to find out whether other concerns have these extraordinary, special privileges of having city water on their premises to put out fires without paying for it, and how much water they are using. That is what we are working on now.

MR. GEORGE CASSELL. Mr. President: I would like to ask Mr. Shedd what disposition was made of the cases he found in his city where they were using water improperly.

MR. SHEDD. Of course the first thing was to stop it, and that was done immediately; but to what extent any punishment has been inflicted, I do not know. That is in the hands of the Commissioner of Public Works.

MR. E. C. BROOKS. Mr. President: Bearing upon what Mr. Richards said about the different character of the cities, I would say that in Cambridge last year, with only six per cent. of the services metered,—and those almost entirely manufacturing supplies,—our sales by meter amounted to 37½ gallons per capita, more than the total consumption of Fall River, a city larger than Cambridge by some eight or ten thousand. So that I think the character of the city in determining what is possible in a low consumption of water is to be taken into account.

This year we will add to that probably not far from three gallons per capita, so that this year our per capita consumption by meter, almost entirely for manufacturing, will be a little rising forty gallons.

I would say here that if any of you have public buildings that you are furnishing water to free of charge, I think it would be a revelation to find out what the consumption of water is in the ordinary schoolhouse. We have a grammar school in our city, not a very large school, but it has used a million and a half gallons of water the past year, making a per capita use of water by the school children that is perfectly enormous. I find that every-

where where the city uses water in public buildings without making any payments to the water department for it, the consumption is very large. Nothing that I have ever found has exceeded in crudeness the management of the ordinary sanitary fixtures in schoolhouses. They are given almost no supervision, and the water is allowed to run continuously.

MR. COGGESHALL. I think we can take the cake on schoolhouse water in New Bedford. In some of the schoolhouses they were using electric motors for running their ventilating fans, but, the water being free for city uses, they installed water motors instead, which use at the rate of some 150 000 gallons a month. It costs the school nothing, and therefore they reason that it costs the city nothing; and the city allows it to go on.

MR. F. N. CONNET. The question was asked a short time ago: What is the average difference between the total reading of the meters and the total amount of water used. In the northeastern corner of New Jersey there is a private water company, managed by one of the members of this Association, and he told me a few days ago that 98 per cent. of his services were metered, but that the meters accounted for 28 per cent. less than the plunger displacement of his pumps.

I want to say a word about the difficulty of ascertaining the amount of water used by a large corporation without a meter. I know of one instance in our own city where it was estimated that the consumption was 50 000 gallons per day, but a meter was put on a few months ago, an 8-inch meter, and the consumption was found to be 280 000 gallons a day.

Now, one other thing. If you noticed the tables Mr. Shedd read, some years ago the population of Providence was about 110 000 and the per capita consumption was about sixty, I think. Last evening I was talking to a man who owns a private water company in the northeastern corner of Pennsylvania, where the number of inhabitants supplied was about 110 000, but the total water supplied per day is between 25 000 000 and 30 000 000 gallons; in other words, the total consumption per capita is from 225 to 250 instead of 60 gallons.

MR. SHEDD. There is, in what I gave, an illustration of the difference between different cities in the quantity of water required per capita, in that about half the takers in Providence are fur-

nished with water at the rate of less than 20 gallons per capita, and the difference between that and 58 gallons per capita is made up in the manufacturing portion of the water supply. In Providence we have, I suppose, an unusually large amount of water required for manufacturing purposes.

MR. CHASE. Mr. President, some of this difference in relation to the per capita consumption in different cities can be explained by the percentage of the population that is supplied with water. If you had cities where every family in each city was supplied with water, then the statistics would be of some value for comparison. The city of Providence has a matter of 85 or 90 per cent. of its population supplied, and the city of Cambridge has 95 per cent., so there would be some difference in the per capita figuring. Then, the slip of the pump is a very important factor, to my mind, and the case cited, I believe, by Mr. Robertson is not an uncommon one. It has been reported to me in several similar cases, where meters were used to a very large extent, that there was practically a very large percentage of the water that was pumped which was not registered by the meters; and that brings up the question as to whether the slip of pumps in general is not very much greater than they are credited with. I might, if the hour were not so late, give you a little personal experience. I would, however, like to ask Mr. Shedd if he wishes to express any opinion in regard to the slip of pumps.

MR. SHEDD. A pump well kept up, well cared for, and originally well constructed, should go through a long period with no more than about 2 per cent. of slip, but I know of pumps which have up to 4½ per cent. of slip. In our case we have kept them within about 2 per cent. of slip, and when they are new I have had measurements made where we had between 1 and 1½ per cent. of slip, when everything was in the best condition. I presume, as a matter of fact, that it varies from 2 to 5 per cent. in different places.

MR. DEXTER BRACKETT. I should like to ask Mr. Shedd in what way the slip was determined.

MR. SHEDD. By measuring all the water delivered by the pump by a weir, and then measuring the pumpage in the usual way, by the stroke of the pump and the area of the plungers. But the amount of water sent through the force main is measured over a weir, and that gives the amount of water actually delivered.

MR. BRACKETT. I wished to ask whether you had means of measuring over a weir the quantity delivered by the pumps.

MR. SHEDD. That is the way of determining it.

MR. BRACKETT. I am surprised that the slip of a pump after being used for several years was not more than 2 per cent. I think such conditions are the exception rather than the rule.

MR. SHEDD. I don't think so. Of course it is expected that the condition of the pumps will be kept up as nicely as possible. After several years of use I have not personally measured the amount of slip, except in this case, where I have found 4½ per cent. slip.

MR. BRACKETT. I have personally measured pumps where there was 50 per cent. slip, and I have known of others where there was 40 per cent., and the slip of pumps used on the Metropolitan works has been found to be from 3 to 18 per cent. With an outside packed plunger pump, there is very little slip or leakage by the plunger, but the rubber valves wear with years of use, and as the valves wear there will be an increase in the amount of slip. You seldom get less than 1 per cent. slip with a new pump. I do not, however, think that it is safe to assume, because there is a large difference between the amount registered by the house meters and the quantity determined by the displacement of the pump plungers, that this is slip.

MR. FOSTER. My experience with pumps has been such as to bear out Mr. Shedd's view. I think that the slip of a pump ought not to be more than 2 to 5 per cent., and I think I am quite prepared to understand Mr. Brackett's having found a slip of 40 per cent. or even 50 per cent., but I do not think that is very good engineering. Of course we all know that there can be only two ways for the pump to slip, — that is, by the water passing the plunger, or passing the valve, — and that brings up the question of the design of the pump and the design of the valve and the nature of the packing of the plunger. I do not think any pump ought to be built with rigid ring packing for anything except very low heads, although I do think that a pump can be operated successfully for a great many years without showing more than a 5 per cent. slip on a solid ring for a head of twenty feet; but I think the slip of a pump goes up very rapidly after a time, if put under a high head.

My experience with the Worthington Company extends over sixteen or seventeen years, and during that time we had some tests of old pumps. One in particular I know had been in use eighteen years, and we had a careful test made of that pump. The valves had been kept in good order and the plungers showed little wear, and we found but 5 per cent. slip in that pump.

I think the question of valves is very often neglected in pumping stations, because the pumps are required to run almost all the time in some places, and the valves are not overhauled often enough. If the valves are overhauled and kept in good order, I am sure you will not find any slip of the valves to amount to anything, — not more than one-half of one per cent.

MR. F. W. DEAN. In regard to this matter of slip, I had occasion to test the old Morris engine at Lowell. I believe I made two tests. It had been in use a great many years, and, if I remember rightly, the slip was found to be in the vicinity of 5 per cent. The water was measured over a weir, and I am under the impression that very little had been done to the pump end during the life of the pump up to that time.

I have been recently informed that in New York the slip has been found to be, if I remember rightly, something like 36 per cent. on one pump, and various amounts less than that on some of the others.

MR. J. C. WHITNEY. I think Mr. Shedd said that the repairing of 20 000 meters cost about $2 200 a year and that it took the services of three men. Now, if Providence pays ordinary machinist wages, how are the necessary repairs borne out of that sum?

MR. SHEDD. Those three men had a great many other things to do besides repairing meters; for instance, they set all the meters and take the readings.

MR. WHITNEY. There is also another question. I think Mr. Shedd stated that by experiment he found a certain composition gave the best satisfaction in the service supply district. Will he be kind enough to state what it is?

MR. SHEDD. The mixture used is in the proportion of 80 pounds of copper, 6 pounds of tin, 3 pounds of zinc, and 2 pounds of lead. The use of lead is for the purpose of securing smooth and easy work in the machine shop.

IMPROVEMENTS IN ECONOMY OF PUMPING ENGINES.

BY F. W. DEAN.

[*Read November* 11, 1903.]

In 1893 I read a paper before this Association giving the briefest notice of some of the oldest types of pumping engines, and an account somewhat fuller of the then prevailing types of pumping engines in the United States. The presence here to-day of Mr. J. Herbert Shedd reminds me to speak of the Cornish engine that was installed in the Pettaconsett Pumping Station of the Providence Water Works when Mr. Shedd designed that system, and of the connection of that time with the fascinating period of Cornish engine prominence in England in the person of Mr. Simeon Noel, the talented engineer whom Mr. Shedd imported from Cornwall to take charge of his engine near Providence. Mr. Noel was one of those thorough Cornish engineers, trained by years of apprenticeship and as engineer in charge of large engines of his favorite type in Cornwall, whom it was a satisfaction to meet. It would be a matter of regret if his name should be forever unmentioned after his death, which took place a number of years ago, and it would be a pleasure to hear some account of him from Mr. Shedd.

I remember how much Mr. Leavitt enjoyed calling on Mr. Noel at the Pettaconsett Pumping Station and conversing upon the topic uppermost in both of their minds. I believe that Mr. Noel was employed at the Fowey Consols Mines in Cornwall when, in 1840, a Cornish engine gave a duty of 120 000 000 foot pounds per 100 pounds of coal when using steam of 12.57 pounds pressure per square inch.

When Mr. Noel was at Pettaconsett, pumping engine controversies and rivalries were beginning to be rife in Providence, and a Worthington duplex compound engine of the ordinary type was put in for spare use. Mr. Noel naturally was sceptical of the success of anything but an engine of the Cornish type, but it fell to him to take charge of the Worthington engine.

Although it was entirely deficient in the grandeur and impressiveness of the Cornish engine, and enjoyed no international reputation, Mr. Noel admitted that he was surprised at the success and reliability with which it operated.

Passing from this short reminiscence to the subject of modern pumping engines, it may be remembered that about the year 1883 there was brought out a Worthington engine with an attachment devised to imitate the effect of a fly wheel, by means of which the steam could be cut off early and worked expansively, and the stroke completed notwithstanding the diminished pressure of the steam in the cylinders due to its expansion. It may not now be as improper as it once would have been to say that I feel that this engine has been a disappointment both in first cost, economy, simplicity, and satisfactory operation. There has thus far been nothing devised which will produce the effect of a fly wheel as well, or as simply, as the fly wheel itself, and I believe that ingenious mechanical minds are now turned to more promising fields of activity.

In my paper of ten years ago I gave a short account of the vertical three-crank Allis triple expansion engine. This engine has been copied by other builders and may now be called a standard type of the country. It has reached the maximum duty that has been obtained, and has the design of valves and valve gear that is indispensable for the most economical results. In my former paper I mentioned that single beat poppet valves were used by the Allis Company in the heads of the low-pressure cylinder. This valve continues to be used, and has sometimes been used in intermediate cylinders, and is used by nearly all makers. It is a circular valve on a spindle that is moved up and down by cams not unlike those used on the beam engines of side-wheel steamers. The steam inlet valves when they open move away from the cylinders, and when they are closed are flush with the face of the head. The exhaust valve is flush with the cylinder head when closed, and opens by entering the cylinder. When it opens and enters the cylinder the piston is near the other end of the cylinder, but when the piston returns the valve is closed and is out of the way.

You have, of course, all heard of the effect on economy of a small volume between the piston when at the end of its stroke and

the valve seat. This is what is called clearance volume, and the smaller it is, the greater the economy. The reason for this is that a portion of the steam which fills it passes into the condenser and is lost. It will be seen that the single beat valve makes the clearance volume the least possible and must produce the greatest possible economy, as far as it affects economy. There is another good effect of this valve. It reduces to the smallest minimum the surface of the interior of the cylinder and thereby diminishes the condensation of steam. In the case of the Corliss and gridiron valves, there is a great deal of surface around the ports, and this produces condensation.

From these considerations it will be seen that nothing can be done in future to design steam cylinders so as to increase the economy of steam.

Somewhat recently a new method of using steam in cylinder jackets and reheaters has been employed. This consists in taking boiler steam into the high-pressure jacket, thence to the first reheater, thence to the intermediate jacket under reduced pressure, thence to the second reheater, and thence to the low-pressure jacket under still further reduced pressure. Reducing the pressure in the low-pressure jacket is important, for otherwise the exhaust of that cylinder will pass to the condenser in a superheated condition, and heat is thus lost.

With cylinders designed in the best conceivable manner, and the best conceivable method of using the steam being employed, what is there left to increase the economy of steam?

There are a few things that can be done to assist. In the first place, a maker should be required to guarantee that after an engine has been run two or three months the valves and pistons should be perfectly tight. This can be determined by trial, and the valves can be scraped tight.

Another thing is that the maker should be required to guarantee a high vacuum in the low-pressure exhaust pipe near the cylinder, say no less than 28 inches. The maker should also be required to furnish a mercury column to show the vacuum instead of, or in addition to, a vacuum gage of the ordinary kind. After having once obtained a high vacuum, the engineer should be required to maintain it.

Recently much attention has been given to condensing appa-

ratus in connection with steam turbines, and more is now known about the best means of obtaining high vacua than has been known heretofore. It is of more importance to obtain a high vacuum with turbines than with reciprocating engines, but with the latter it is of sufficient importance, in the interest of economy, to insist upon the best obtainable vacuum.

It has been thought that in addition to the usual air pump an additional pump, known as a dry-air pump, should be used, whose function is to remove the air that comes through with the steam or that leaks in. Usually this air is swept along into the condenser pump, which has been called the air pump for the reason that it pumps this air. The dry-air pump simply helps the other pump along, and it is quite probable that a larger ordinary air pump would do as much good. At all events there are cases where a vacuum of 29 inches has been maintained without a dry-air pump, as in the cases of the Louisville pumping engine and the steam turbine plant at Newport, R. I.

An advisable adjunct of the high-vacuum apparatus is an air cooler, which makes the volume of air to be pumped smaller.

The most prominent means of promoting economy, however, at the present time, is the use of superheated steam. This has been in use in Europe for a longer time than in this country, and has been especially promoted in Germany. There is no doubt that it reduces steam consumption to a great extent. If we look at the records of the test of the Louisville pumping engine, for example, we shall see that while the engine as a whole used 12.16 pounds of dry steam per indicated horse-power per hour, the cylinders themselves used only 10.12 pounds. Of course this economical cylinder performance was caused by the superheating effect of the jackets and reheater. If now some external appliance could superheat the steam to such an extent that the engine as a whole would use as little steam as the cylinders did alone, the total economy of steam would be greatly improved and the duty would have been 182 000 000 foot pounds instead of 152 000 000 foot pounds per 1 000 pounds of dry steam. It would be perfectly possible to do this, and even the Louisville engine could, without doubt, be made to give a duty of, say, 180 000 000 foot pounds or even more by the use of superheated steam.

While this is perfectly true, the question arises, At what cost in fuel can the steam be superheated? On this point there is but little information available. If the steam could be superheated by waste gases from the boiler it would be all gain, but it can only be done some 25 to 35 degrees by means of the vertical type of boiler. This is, of course, advantageous, and I have been informed that the most economical cotton mills are those with Manning boilers.

There is one thing that can often be done, and it seems to me that it always ought to be, when not impracticable, and that is to reheat the steam between the cylinders by means of the gases from the boilers instead of by means of live steam. I designed such a reheater a number of years ago, but not until recently was one used. This I designed for the Barr engine at Haverhill, with the result that the duty was found on each of two tests to be about 150 000 000 foot pounds per 1 000 pounds of steam. An engine of this type and size with a steam reheater gives about 128 000 000 foot pounds duty. The gases in this case superheated the steam betweeen the cylinders about 60 degrees F., and this it was able to do because the pressure of steam between the cylinders is so low. Here is a clear gain at no cost for fuel, and small cost for apparatus.

In regard to methods of superheating steam at boiler pressure, it can be done in connection with superheaters in the boiler setting, or in separate furnaces. In the former case sometimes the superheat varies with the intensity of the fire as determined by the damper regulator, while sometimes the superheat can be kept approximately constant by means of dampers for varying the supply of hot gases to the superheater regardless of the intensity of the fire.

Separate superheaters can raise the temperature of the steam to any reasonable amount, and these are held by many to be the most desirable form, not only on this account, but because the degree of superheat can be controlled. If they are used the fuel is quite an item, and the escaping gases should be used for heating feed water.

Tests have been recently made in Philadelphia of a Rice & Sargent compound engine, without steam jackets, with a reheater, and provided with Edge Moor water tube boilers and a separate

Schmidt superheater, by Albert C. Wood and Prof. D. S. Jacobus. The guarantee was that the engine should not use more than 10½ pounds of steam per indicated horse-power per hour with the steam at 140 pounds and superheated from 240 to 290 degrees F. With ordinary dry steam the engine was guaranteed to consume not more than 13½ pounds.

The following are some of the results:

Date of test, June 19 and 20.	
Duration, 14 hours.	
Average temperature of steam entering superheater,	367° F.
" " " " leaving "	814° F.
" " " escaping gases,	472° F.
" " " steam at throttle,	736° F.
" " " " " h. p. cylinder,	659° F.
" " " exhaust at h. p. "	332° F.
" " " steam " l. p. "	396° F.
" " " exhaust of l. p. "	128° F.
Average steam consumption per I. H. P. per hour, with superheated steam,	9.68 lbs.
do. with saturated steam on July 24,	13.81 lbs.
Coal used per I. H. P. per hour with saturated steam,	1.41 lbs.
do. with superheated steam,	1.23 lbs.
Saving, 1.41 — 1.23 = 0.18 lbs. =	12.7%
Applying all corrections the report calls the saving,	14.52%

You have many times had your attention called to the different methods of stating and computing the duty of pumping engines and the arguments for them. The coal method is, of course, the commercial method, but it is obviously improper when only an engine is purchased and the maker is required to guarantee his engine. For this purpose the duty is usually based upon the consumption of 1 000 pounds of dry steam. The more proper method, although one that fails to become popular, is the heat unit method. It is more correct, because the steam engine is a heat engine, and heat does the work. The method by weight of steam is not quite right, because different steam pressures and different qualities of steam are used at different times, and therefore 1 000 pounds of steam does not always contain the same number of units of heat.

The method by heat units is somewhat laborious, and requires some knowledge of the properties of heat. It may be outlined as follows: When steam passes into a steam cylinder, or series of cylinders, it has a certain number of units of heat in each pound. This is made up of the heat of vaporization and of the

liquid of the same temperature, and if it is superheated, an additional amount. When it leaves the engine it has the heat corresponding to the temperature of the discharge from the condenser, as shown by a thermometer in the hot well. The difference between these quantities has been used by the engine. If the engine has jackets and reheaters, the same number of units of heat exists in each pound entering them, but as the condensation leaving these parts is hotter than the condenser discharge, a different number of units of heat leaves the jackets and reheaters. Subtracting the number leaving from the number entering gives the number used by these accessories, per pound. By multiplying the number in a pound by the number of pounds passing through the cylinders, and similarly with the steam passing through the jackets and reheaters, and adding them together, there results the total number of units of heat used by the engine. This sum is then used in computing the duty. While it is simple enough after one becomes familiar with it, I do not believe that it will ever become sufficiently popular to be often used.

While upon this subject I want to urge you not to specify unusual methods of computing the duty when purchasing a new engine. The reason for this is that a standard method is in force, and has for its object the existence of something with which comparisons can be made, and thus to have the means of judging of the excellence of a new engine, or of the perfection of maintenance of an old one. If a new method of determining the duty of an engine is used the result cannot be compared with the standard, and therefore there are no means of knowing whether the new engine is good or not.

RAINFALL AND RUN-OFF FROM CATCHMENT AREAS IN NEW ENGLAND.

BY L. M. HASTINGS, CIVIL ENGINEER, CAMBRIDGE, MASS.

[*Read December* 9, 1903.]

The preparation of a reliable estimate of the flow or run-off which may be expected from a given catchment area is a matter often of vital interest to manufacturers, municipal officers, and engineers. Upon the correctness of these estimates may depend the success or failure of large enterprises requiring the investment of many thousands of dollars of capital, or the comfort, health, and even the lives of thousands of people dependent for water upon the adequacy of a public water supply.

Every consideration of prudence and public safety points to the requirement that such an estimate be not over sanguine in its anticipated results, else in the case of a stream developed for power, disappointment may come from a stream overdeveloped and so working uneconomically; or in the case of public water supply, the capacity of the works may be found disappointingly small, which usually means an extension and increase of the supply. It seems to be generally true that but few works have given as large a supply or have served the community as long as was at first expected.

It is wise, therefore, that all the data of value relating to the subject should be collected and the entire question studied with great care. Realizing this, the United States Government has caused an extended series of investigations to be made into the subject, the reports giving the results of which form a series of valuable papers. Some of the states — notably the state of New Jersey, in a valuable report published in 1894 — have done the same thing. The subject has also been quite fully discussed in various papers published in the *Transactions of the American Society of Civil Engineers*.

While the best method of determining the run-off from a given area is to measure the flow of the stream draining the area, yet

it is seldom possible to carry these measurements over a period long enough to be of much value in determining the average or the minimum flow — so, often, other means are necessary.

RAINFALL.

As the rainfall upon an area, its amount and distribution, is the most important element in determining the run-off, it naturally receives the largest share of attention. For a considerable period now, observations of temperature and rainfall have been kept in a satisfactory manner at many points in the country, under the auspices of the United States Weather Bureau. While these observations have not yet been extended enough in time to be taken except in the absence of other rainfall records carried over longer periods, there can be no doubt that in the future they will prove invaluable.

In New England and the eastern states many private observers have records of rainfall extending back to the early part of the last century. While into these earlier records, it is true, some errors may have crept, and while it is probable that the same care was not taken (especially in the measurement of snow) as is now required, they will, nevertheless, prove of interest, and the error, if any, may be expected to be on the side of safety in at least not overestimating the amounts.

Two interesting questions occur here: How many years' observations are required to give a fairly reliable average result? and, Within what period is the minimum rainfall liable to occur?

With regard to the first question, the longer the period considered, of course, the more reliable the result and the less will the average obtained depart from the true average. Mr. Alexander Binnie, an English engineer, in a paper read before the Institute of Civil Engineers, in 1892, on "Variation in the Amount of Rainfall," examined over 150 long-time records of rainfall obtained in various parts of the world, — the United States, Great Britain, the European Continent, and India, — and from the numerous cases cited draws the conclusion that "dependence can be placed on any good record of thirty-five years' duration to give a mean rainfall correct within 2 per cent. of the truth." For records of twenty years' duration, the error may be expected to be 3.25 per cent.

Mr. Alfred J. Henry, chief of division, United States Weather Bureau, in a paper on "Rainfall of the United States," 1896, finds by comparing some long-time records obtained in this country that at least thirty-five to forty years' observations are required to obtain a result that will not depart more than 5 per cent. above or below the true normal average.

The second question will be referred to later.

Upon Plates I and II are shown diagrammatically the annual rainfall for eight localities in full lines, while the annual average by ten-year periods is shown in broken lines.

The Lowell rainfall diagram is from records kept by the Proprietors of Locks and Canals at Lowell. The Waltham diagram is from records kept by the Boston Manufacturing Company. Providence and New Bedford rainfall are taken from a report by Mr. A. T. Safford to the Fall River Reservoir Commission, 1902. Boston rainfall, 1820 to 1891, is taken from Mr. D. FitzGerald's paper in *Transactions American Society of Civil Engineers*, 1892; for 1892–1900, Sudbury River rainfall (from report of Metropolitan Water and Sewerage Board, 1901), is used to complete the Boston record. New York rainfall, 1836–1868, is from the report of Isaac Newton on New York Water Supply, 1882; and 1868 to 1899 from the report of J. R. Freeman, 1900. Philadelphia rainfall, 1824 to 1889, is from report on geological survey of New Jersey, 1894; 1890 to 1900, from department of public works, Philadelphia.

An inspection of these diagrams will at once suggest the question, Is our rainfall increasing? Prof. Mark W. Harrington, in a paper on "Rainfall and Snow in the United States," in *Bulletin "C," Weather Bureau*, examined this question, but as the data were so contradictory and inconclusive he reached no definite conclusion. He was inclined, however, to answer the question in the negative. If the rainfall records shown on the diagrams taken in the early periods were as reliable as those obtained later, the conclusion from some of them — notably Nos. 1 to 4 — might be drawn that the rainfall *was* increasing. Some of the records, on the other hand, show that a maximum was reached in the middle of the last century, and that the rainfall is now decreasing. Attention should be called to the extremely high average shown in the Boston record for the period 1861 to 1870 the average, 57.30

inches, being far above that of any other period shown. A study of the following tabulation of the averages may also be instructive.

TABLE No. 1.

SHOWING AVERAGE ANNUAL RAINFALL (INCHES) BY TEN-YEAR PERIODS.

PLACE.	-1830.	1831-1840.	1841-1850.	1851-1860.	1861-1870.	1871-1880.	1881-1890.	1891-1900.
Providence	..	36.87	41.21	43.73	47.56	47.84	49.07	48.90
New Bedford	..	44.27	44.94	44.76	46.27	46.88	48.69	47.72
Waltham	42.25±	40.49	40.74	42.84	42.52	40.66	44.15	44.74
Lowell	40.31±	39.35	40.27	*46.54	45.93	45.24	46.46	44.47
				44.14	44.07	42.65	46.76	40.93
Boston	39.61	41.18	42.92	50.03	†57.30	50.26	48.78	46.37
Harvard Observatory	..	...	43.28	49.23	45.23	44.99	44.60	41.19
Philadelphia	38.01±	42.40	45.24	44.25	46.74	42.21	39.59	40.38
New York & Croton	.	41.55±	42.47	48.22	53.19	44.81	51.21	48.37
Worcester	..	...	42.80	52.46	44.35	‡41.58	42.75	42.82

*Second observing station. †Observe the abnormally large rainfall. ‡Six years 1875-1880.

An inspection of the diagrams might also suggest the query whether, in certain cases, especially in the designing of works whose life was expected to be limited to a short period, say twenty or thirty years, it might not be best to consider the rainfall average obtained from a comparatively short time.

If the rainfall in certain localities is increasing, a long period average will give too low a result; while, on the other hand, if the period of maximum rainfall has passed and it is now decreasing, the inclusion of that period of large rainfall might give too large an average.

The range or variation in the amount of annual rainfall is remarkable, especially in the Boston record, the maximum amount being 67.72 inches in 1863, and the minimum being 35.56 inches in 1883, while at Sudbury River the rainfall for 1883 is given as 32.78 inches.

Another interesting fact shown by the diagrams is that years of large or maximum rainfall recur at intervals of approximately ten years, while the years of low or minimum rainfall recur at much longer intervals.

DISTRIBUTION OF RAINFALL.

In a study of rainfall in its relation to run-off, its *seasonal distribution* through the year is important. Mr. Clemens

Herschel, hydraulic engineer, of New York, in discussing this subject says,

"Observations show, however, that the distribution of rainfall, the times and the rates at which it falls, have a most potent effect on the relation. Hence it is that years of practically the same rainfall have widely differing amounts of run-off, not to speak of the differences of yield of months and single showers having the same measure of inches of rain."

"It is in the study of the effect of these additional factors upon the run-off of streams, in the study of effect of slopes, of the quality of surface, and to some extent of the distribution of rainfall, that the customary percentage proportions of rainfall to flow of streams, have their proper place and have value."

The diagrams already referred to show the rainfall for the various localities and years as though it were uniformly distributed throughout the year: such of course is not the case.

The heavy full lines upon the diagrams, Figs. 1, 2 and 3, show the average rainfall by months as observed at Philadelphia, Harvard Observatory, and Sudbury River, Boston Water Works.

It is interesting to observe that the average monthly rainfall does not vary greatly, but on the whole the rainfall is rather uniformly distributed throughout the year, also that the maximum amount at Philadelphia, Harvard Observatory, New York, and many other places occurs in *August* (commonly supposed to be a dry month). Extremely large rainfalls are also recorded for this month at many stations — 15 inches at Harvard Observatory, and 16.84 inches at Philadelphia. The broken line shows in each case the rainfall of an exceptional year and indicates the wide monthly range which sometimes occurs.

RAIN GAGES.

It is often important to study rainfall for periods shorter than a month. For this purpose the records obtained by the automatic rain gage are extremely useful. Such gages are now constructed and sold at a moderate cost, are quite reliable, and give results which cannot fail to be instructive, for they record not only the *amount* of precipitation up to any given time, but they also show the *rate* at which it has occurred at any time, often an important factor. The diagram, Fig. 5, shows four records which were obtained in the summer of 1900 by an auto-

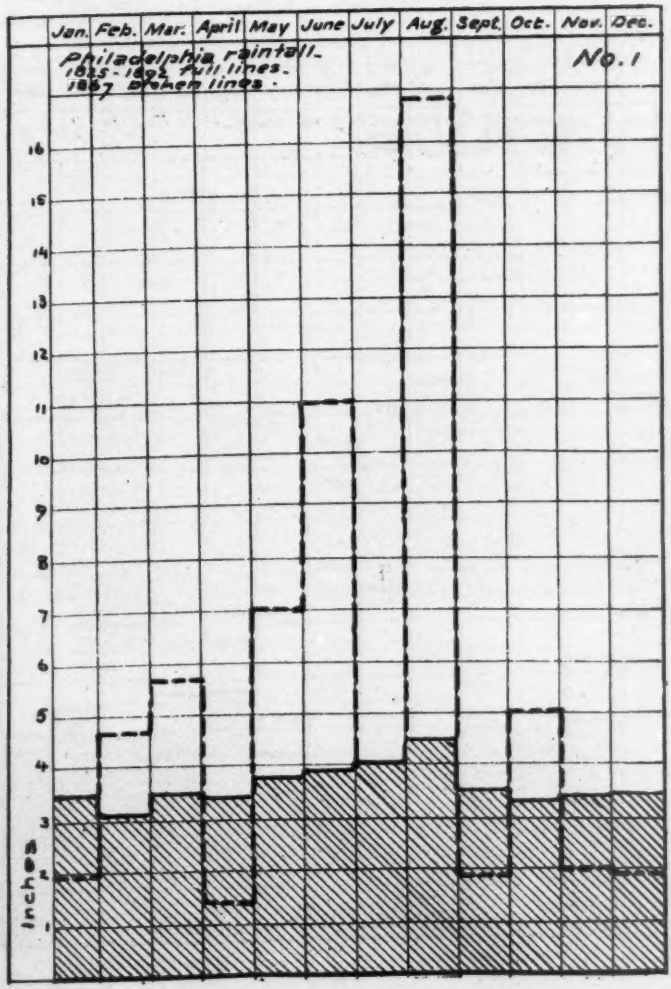

Jan.
Feb.
Mar.
April
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
Philadelphia rainfall.
1825-1892. Full lines.
1867 Broken lines.
No. 1
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
Inches

FIG. 1.

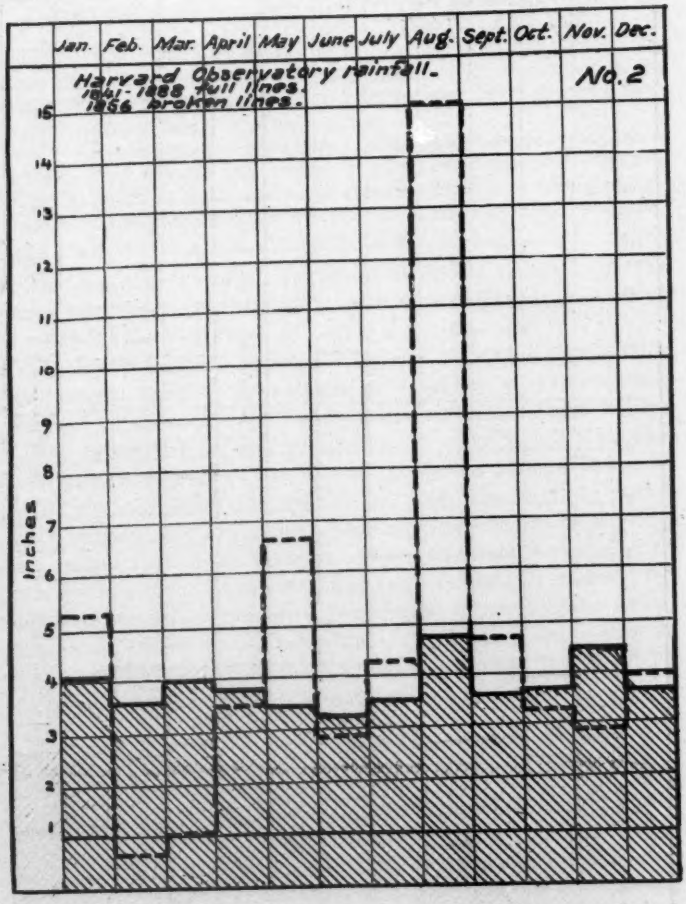
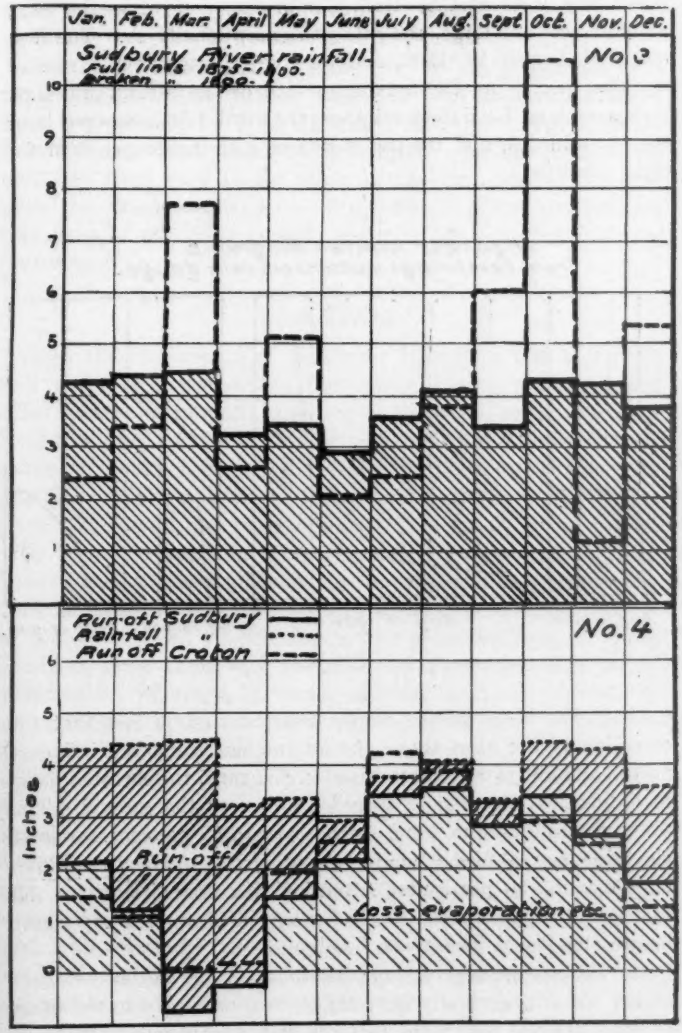

Jan.
Feb.
Mar.
April
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
Harvard Observatory rainfall.
1861-1888 full lines.
1856 broken lines.
No. 2
Inches
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1

FIG. 2.


Jan.
Feb.
Mar.
April
May
June
July
Aug.
Sept
Oct.
Nov.
Dec.
Sudbury River rainfall.
Full lines 1875-1900.
Broken " 1892.
No 3
10
9
8
7
6
5
4
3
2
1
Run-off Sudbury
Rainfall "
Run off Croton
No. 4
Inches
6
5
4
3
2
1
0
Run-off
Loss - evaporation etc.

FIGS. 3 AND 4.

matic rain gage at City Hall, Cambridge, and while the total amount was not large, the *rate* was exceptionally so. The first occurred August 10, 1900, and for five minutes gave a rate of 6 inches per hour; the maximum rate of the second was 2.81 inches per hour for sixteen minutes; the third, 1.80 inches per hour for ten minutes, and the last a rate of 3.75 inches per hour for eight minutes.

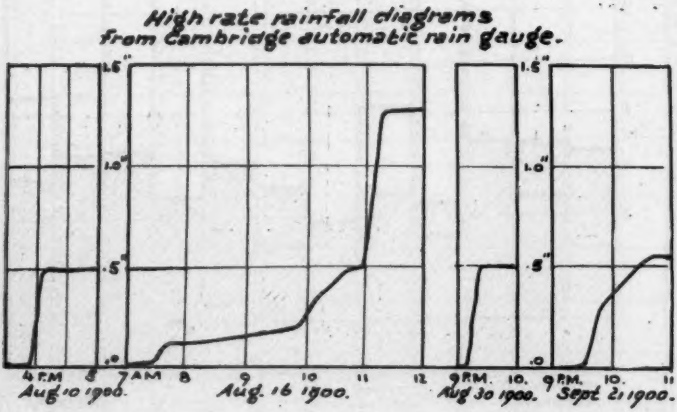


FIG. 5.

Much has been written concerning the curious fact that the elevation of the gage above the ground has a marked influence on the amount of rainfall received in the gage, the elevated gages recording less than those placed at or near the ground. This difference amounts in some cases to 10 to 15 per cent. for small elevation, say 20 feet, while for elevations of 150 feet the difference may be 50 per cent. Attention was first directed to this fact by an English scientist, Heberden, in 1769, in a paper read before the Royal Society of London.

No entirely satisfactory explanation of this has as yet been given, but it is generally believed to be due largely to the effect of wind playing about the receiver of the rain gage. Professor Nipher of St. Louis claims that with a suitably constructed wind

guard or shield the gages will record the same, regardless of their elevation.

This subject has been discussed by Mr. D. FitzGerald in a paper read before the Boston Society of Civil Engineers, August, 1884, and recently by Prof. Cleveland Abbe in a report to the United States Department of Agriculture. As but little attention has been paid to the effect of the elevation of the gage upon the amount collected until recently, it seems not unlikely that some of the older records are more or less inaccurate for that reason.

EVAPORATION.

Since the major part of the water falling on the land must flow from it or be evaporated, the matter of evaporation is closely allied to that of rainfall, especially if there are large water surfaces contained in the catchment area. It is supposed that the annual evaporation bears some relation to the mean annual temperature and the rainfall, and thus having these two quantities given, the run-off can be computed.

Mr. C. C. Vermeule, in a report to the state geologist of New Jersey, 1894, suggests an ingenious formula expressing this relation. This formula he has modified slightly in a subsequent report on forests in 1899. While the results given by it agree quite closely in some cases with the observed quantities, in others a considerable difference is noted, showing that the formula is useful only when the conditions are similar to those from which the formula was deduced.

The evaporation from water surfaces has been extensively studied in this country. As is well known, Mr. FitzGerald carried out a very elaborate series of experiments and observations to determine the amount and the law of evaporation from water surfaces, and described the same in a paper found in the *Transactions of the American Society of Civil Engineers*, 1886. Mr. Arthur T. Safford, C.E., in a report on the water supply of Fall River, Mass., 1902, reports observations of the evaporation during the years 1899, 1900, and 1901, near that city. Observations have also been carried on at New York, Philadelphia, and other places.

The mean annual evaporation given by Mr. FitzGerald is 39.12 inches, or 85 per cent. of the mean annual rainfall.

Little experimental data seems to be available of the evaporation from the soil in this country. Mr. J. T. Fanning, in his treatise on "Water Supply Engineering," quotes some English experiments on evaporation from the soil. One set at Whitehaven, England, 1844 to 1853, gave an evaporation of 29.21 inches, with a rainfall of 43.50 or 69.1 per cent. Another at Lee Bridge, 1860 to 1873, gave an evaporation from soil of 19.534 inches on a rainfall of 27.7 inches, or 70 per cent. None of these figures probably include the water absorbed and transpired by vegetable and plant life.

In the absence of experimental data to determine the evaporation from land, the total loss by evaporation, absorption by plant life, and percolation, may readily be determined in streams where the run-off has been observed, and indeed, this method is in many respects more reliable than any experimental observations could be, as it may be carried out on a large scale under conditions as they actually occur in nature.

TABLE No. 2.

SHOWING LOSS BY EVAPORATION, ETC., ON SUDBURY AND CROTON RIVER AREAS.

Month.	Sudbury River 1875-1900.			Croton River 1868-1899.			Sudbury River 1883.			Croton River 1880.			Water Surface Evaporation (Inches).
	Rainfall (Inches).	Run-off (Inches).	Loss Evaporation, etc. (Inches).	Rainfall (Inches).	Run-off (Inches).	Loss Evaporation, etc. (Inches).	Rainfall (Inches).	Run-off (Inches).	Loss Evaporation, etc (Inches).	Rainfall (Inches).	Run-off (Inches).	Loss Evaporation, etc. (Inches).	
Jan.	4.35	2.20	2.15	4.20	2.69	1.51	2.81	0.60	2.21				0.98
Feb.	4.44	3.17	1.27	4.13	2.99	1.14	3.87	1.66	2.21				1.01
Mar.	4.48	5.23	- .75	4.03	3.91	0.12	1.78	2.87	-1.09				1.45
Apr.	3.22	3.44	-0.22	3.18	2.98	0.20	1.84	2.33	- .49				2.39
May	3.37	1.95	1.42	3.78	1.84	1.94	4.19	1.67	2.52				3.82
June	2.93	0.81	2.12	3.36	0.87	2.49	2.40	0.52	1.88				5.34
July	3.72	0.34	3.38	4.87	0.60	4.27	2.68	0.20	2.48				6.27
Aug.	4.09	0.53	3.56	4.87	0.99	3.88	0.73	0.14	.59				5.97
Sept.	3.24	0.41	2.83	4.02	0.84	3.18	1.52	0.16	1.36				4.86
Oct.	4.35	0.93	3.42	3.80	0.94	2.86	5.60	0.33	5.27				3.47
Nov.	4.27	1.62	2.65	4.12	1.72	2.40	1.81	0.35	1.46				2.24
Dec.	3.55	1.86	1.69	3.71	2.13	1.58	3.55	0.35	3.20				1.38
Total	46.01	22.49	23.52	48.07	22.50	25.57	32.78	11.18	21.60	36.92	12.63	24.29	39.12

In Table No. 2, the losses by evaporation, etc., for the Sudbury and Croton River areas are shown, together with the average evaporation from a water surface, as given by Mr. FitzGerald. From this it appears that the total losses from a land surface are but 60 per cent. of the evaporation from a water surface. It is interesting also to note the close ratio the total loss has to the rainfall in the two areas compared. The average on the Sudbury is 51.1 per cent. and on the Croton 53.2 per cent., while for the year of lowest rainfall, 1883, on the Sudbury, it was 66 per cent., and for the lowest year on the Croton, 1880, it was the same — 66 per cent.

This relation of rainfall, run-off, and loss on the Sudbury River area is also shown graphically on the diagrams, Figs. 4 and 6, where the rainfall mass is shown in two parts, the heavier shaded portion representing the run-off, and the lighter shaded portion, the loss by evaporation, etc.

The exceedingly small mass of run-off in July, August, and September illustrates the dryness of these months and the value of storage reservoirs to enable the surplus run-off of the preceding months to be carried over and used then to bring up the low flow.

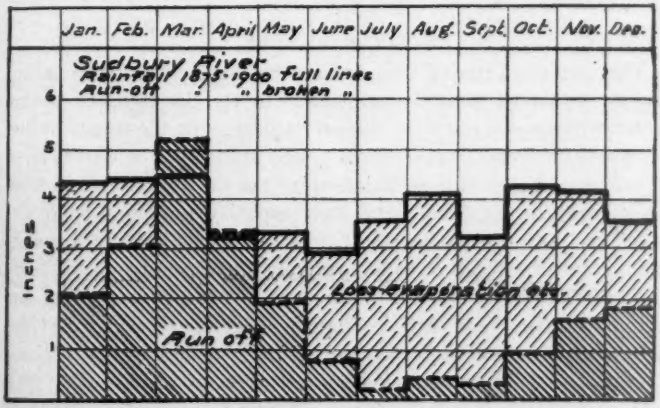


FIG. 6.

It seems to be a fortunate provision of nature that the annual amount of evaporation does not vary greatly from year to year.

Thus, the loss on the Sudbury River area for 1883, the dryest year recorded there, varied less than 2 inches from the average loss for twenty-six years; and the same is true of the Croton River area.

Mr. George W. Rafter, in an excellent paper on the "Relation of Rainfall to Run-off," *United States Geological Survey*, 1903, in speaking of what he calls the "persistency of rates of evaporation," says:

"The persistency of the amount of evaporation for any given stream at about the same figure through long periods of time was first pointed out by Messrs. Lawes, Gilbert, and Warrington in their classical paper, "On the Amount and Composition of Rain," etc., in 1881.

"As to *why* evaporation exhibits such persistency, these distinguished authors consider it largely due to the fact that the two principal conditions which determine large evaporation — namely, excessive heat and abundant rainfall —very rarely occur together. The result is, especially in the English climate, a balance of conditions unfavorable to large evaporation. In a wet season, when the soil is kept well supplied with water, there is at the same time an atmosphere more or less saturated, with an absence of sunshine, while in dry seasons the scarcity of rain results in great dryness of the soil, with scant, slow evaporation."

MAXIMUM RUN-OFF.

The maximum run-off from an area has little commercial value, and is important to study principally in the designing of works which will remove the flow without damage. In the construction of sewers, culverts, water courses, and spillways for dams, it is of the utmost importance to determine the maximum rate of flow which may be expected, that their capacity may not be overtaxed and serious damage result. In the determination of maximum rates of rainfall on comparatively small areas as a preliminary to estimating the maximum rate of run-off, the use of an automatic rain gage will be found of great service. Having determined the maximum rate of rainfall for the length of time it takes the flood wave to reach the culvert or sewer outlet, the rate of discharge or maximum run-off may be computed with fair accuracy by the use of formulas, with the aid of coefficients adapted to meet the conditions of the case in hand. In the city of Cambridge, for instance, it was found that for twenty-minute

periods the maximum rate of rainfall to be expected was 2.5 inches per hour, and so all storm-water drains, culverts, etc., are designed to take the flow produced by that rate, using to determine this flow, the formula proposed by Burkli-Ziegler and adapted by Rudolph Hering, adopting a variable coefficient suited to the character of the surface of the area considered.

In most cases actual gagings of a stream or water course of this character are extremely difficult, as the effect of a sudden shower or burst of rain is soon over and the " flood wave " gone.

In cases like this, self-registering gages are of great service. Interesting results have been obtained by their use at Cambridge and at Hartford and Philadelphia, in connection with sewer work undertaken by these cities.

Of the flood flow from large areas, little exact information can be given. Mr. Vermeule, in his report already referred to, has compiled a table which gives the maximum and minimum flow from many areas of varying sizes. Some of the figures are here reproduced, the areas being arranged in the order of sizes. In general, it may be said that the larger areas give smaller rates of flood flow, while the smaller areas give smaller rates of minimum flow. This tendency is also referred to in the comparison of the flow from New England areas farther on in this paper.

Stream.	Catchment Area, sq. miles.	Maximum Flow, cu. ft. per sec. per sq. mile.	Minimum Flow, cu. ft. per sec. per sq. mile.
Ohio River	19 000.0	6.17	0.114
Potomac River	11 476.0	15.25	0.093
Connecticut River	10 234.0	20.27	0.510
Kanawha River	8 900.0	13.49	0.123
Delaware River	6 770.0	37.50	0.170
Merrimac River *	4 664.0	20.87	0.310
Raritan River	879.0	59.50	0.200
Passaic River	796.9	24.20	0.190
Concord River	361.0	12.32	0.170
Croton River	338.8	74.87	0.150
Ramapo River	159.5	66.10	0.140
Perkiomen River	152.0	34.90	0.050
Neshaminy River	139.3	41.40	0.009
Tohickon Creek	102.2	54.30	0.001
Sudbury River	75.2	41.38	0.036
Croton River, West Branch	20.3	54.44	0.020

* Including Nashua, Sudbury and Cochituate catchment areas, amounting to 213 sq. miles.

MEAN RUN-OFF.

In estimating the flow of a stream for power purposes the mean or average flow is of importance, as it is then desired to know the maximum flow of the stream in an average year to which it will be wise to develop the power and construct the wheel plant, so that as full use of the water power as is possible may be made; also, how much below this maximum or "full power" will the stream fall during dry times, when water power will have to be supplemented with steam. Here, again, long-time gagings of the stream itself are the most reliable of any data. Sometimes gagings of a stream similarly situated may be used and applied to the case, or, if no gagings are obtainable, but a good rainfall record is to be had, the probable run-off can be computed from that by formula. Mr. Vermeule, in his report, has suggested a method by which this may be done.

Probably the average flow of streams and their value for power and manufacturing purposes are matters about which more litigation has been had than any other question in hydraulics. Many communities of New England and their water-works officials have had occasion to know and appreciate the value of water as power from the numerous suits brought to recover damages, by reason of the diversion of said water for domestic purposes.

MINIMUM RUN-OFF.

For water-works purposes the minimum seasonal run-off from an area is of the most importance, and it is the question which should be given the most consideration. As most water works have storage reservoirs of more or less capacity, the absolute minimum flow for a few days is not of so much importance as the length of time a low or minimum flow may continue. It is a fact to be remembered in this connection that the year of lowest rainfall may not give a period of lowest run-off. The *distribution* of the rainfall has an important effect on that question. Mr. Rafter, already quoted, says that

"the total run-off of a stream in any given year depends very largely on the run-off of what may be called the 'storage period.' Usually about 0.75 or 0.85 of the total rainfall of this period appears as run-off in the stream, while for summer, or the growing period, not more than 0.10 of the rainfall appears. This great difference is due to greater evaporation as well as to the absorp-

tion of water by plants during this period. Whether any given stream is low during the summer months, or has then a well-sustained flow, will depend very largely on the rainfall of *May*. When the May rainfall is heavy enough to produce full ground water, the flow is likely to be well sustained, even though the rainfall is comparatively low during the summer months following. If, on the contrary, the May rainfall is so low as to leave a deficiency in ground water for that month, the flow will be low during the summer, even though the rainfall is large. What is wanted, therefore, in a stream is as large a ground flow as is possible, with small evaporation."

Upon the diagram (Fig. 6) is shown the average rainfall for the Sudbury River area, 1875 to 1900, and by broken lines is shown the run-off for the same period, expressed in inches. In March the run-off exceeds the rainfall, while for the six months from June to November the run-off is much less than the rainfall, due to losses by evaporation, absorption by vegetation, etc.

There is a marked difference in the *percentage* of rainfall appearing as run-off, between years of large and years of small rainfall, especially if in the area there are large water surfaces. Thus in the Sudbury River area, with 6.5 per cent. water surface, the average run-off is 48.8 per cent. of the average rainfall, while in 1880, with a low rainfall, only 31.8 per cent. ran off. In a year of large rainfall 62.2 per cent. was collected. On the Croton River, N. Y., area in 1868, 66.2 per cent. of the rainfall was collected, and in 1883 only 31.2 per cent. was collected.

An inspection of the rainfall diagrams on Plate I will be of interest regarding the question of frequency and duration of periods of low annual rainfall as affecting minimum run-off.

If 35 inches be taken as the measure of extreme low rainfall, it is found that annual rainfalls not exceeding that have occurred as follows:

Waltham	8	years	1825 1844 1846 1874 1879 1880 1882 1883
Harvard Observatory	5	„	1844 1846 1866 1883 1894
Boston	4	„	1822 1828 1837 1846
Providence	5	„	1833 1835 1837 1846 1849
New Bedford	1	„	1846
Lowell	7	„	1826 1834 1835 1837 1846 1891 1894
Philadelphia	9	„	1825 1834 1856 1878 1880 1881 1885 1890 1895
New York & Croton	5	„	1836 1840 1842 1845 1849

From this it appears that it is but rarely that two years of low rainfall occur consecutively, although it is possible that years of

low run-off may occur oftener if the rainfall is so distributed to produce that result.

GROUND WATER.

The elevation and amount of ground water stored on an area does seem to affect the dry-weather flow to a marked degree, it being noted that streams from an area largely of open, porous soils give a larger dry-weather flow than those from areas having soils of a clayey, impervious nature.

FORESTATION.

The amount of forestation on an area is also believed to affect the run-off to some extent, especially the minimum rate, although a wide difference of opinion seems to exist as to the extent of this influence. Mr. Rafter says that the presence or absence of dense forests on catchment areas in New York state may make a difference of as much as 5 or 6 inches in the annual run-off from the entire area.

He also thinks,

"that the removal of forests decreases stream flow by allowing freer circulation of air and by causing higher temperature and lower humidity in summer, and so producing greater evaporation from water surfaces as well as from the ground."

"That the removal of forests renders stream flow less equal throughout the year, and so causes floods and periods of dryness in rivers, seems to be beyond reasonable question, for the forest litter and root masses serve as storage reservoirs — tendency to equalize the flow of streams."

Mr. Vermeule states,

"that there is nothing in our observations of stream flow which indicates that forests or other vegetation have any marked effect upon the *total annual evaporation* from a watershed, but that upon deforested areas we may show that moderately heavy floods are now prevalent, and periods of very low flow more frequent and longer extended."

"The effect of forests in holding and preserving the soil upon slopes is very well known, and besides this they create a mass of humus and absorbent matter upon the surface which has an effect upon stream flow, and the general evils resulting from deforestation are a matter of careful observation and record, so that too much stress cannot be laid upon the desirability of preserving a proper area of forests."

"So far as they affect the flow of streams we consider their

most valuable service to be that they *equalize the flow*, which they do to a marked extent."

SIZE OF AREA.

The size of the catchment area has also been held by some to affect the run-off and its distribution. The table already given from Mr. Vermeule's report would seem to support that view.

In order to compare the run-off at different seasons from New England areas, varying widely in size, but similar in other characteristics, the exhibit on the following pages was prepared (Table No. 3).

The areas considered are the Merrimac River area, containing 4 451 square miles; Nashua River, 119 square miles; Sudbury River, 75.2 square miles; Stony Brook (Waltham), 22 square miles; and several small brook areas in Fall River, containing from 5.45 to less than one square mile area. The years selected were 1899, 1900, and 1901, because the observations on the Fall River brooks were taken on these years only. These figures are taken from the excellent report made by Mr. Arthur T. Safford, consulting engineer to the Reservoir Commission of Fall River, in 1902. The year 1899 had a little less than the average rainfall, while 1900 and 1901 had a little more than the average.

In comparing the average daily run-off from the areas given for each of the three years, it will be seen that the rate is remarkably uniform considering the different sources from which the records were obtained, the total average run off from the seven areas for the three years being 1 063 000 gallons daily per square mile of area.

The average run-off for the wet periods, December to May inclusive, on the other hand, show a tendency to increase with the decrease in catchment area. The average run-off for the dry periods, June to August inclusive, show a marked decrease with the decrease in the size of catchment area — and the same in some degree may be said of the following period, September to November inclusive.

Another interesting fact to be noted from an inspection of the figures is, that while the average yearly flow from the Sudbury River area is about the same as the others shown, the run-off during the dry period is *extremely small*, much smaller even than that from the smallest area.

TABLE No. 3.

EXHIBIT SHOWING RUN-OFF FROM CATCHMENT AREAS OF VARYING SIZES IN NEW ENGLAND.

	Merrimac River 4 451 sq. mi. Catchment.	Nashua River 119 sq. mi. Catchment. 2.2% water surface.		Sudbury River 75.2 sq. mi. Catchment. 6.5% water surface.		Stony Brook, Waltham 22 sq. mi. Catchment. 5.4% water surface.		Fall River			
	Gals. daily per square mile.	Rainfall Inches.	Gals. d.p.s.m.	Rainfall Inches.	Gals. d.p.s.m.	Rainfall Inches.	Gals. d.p.s.m.	Rainfall Inches.	North Ponds 5.45 sq. mi. Catchment. Gals. d.p.s.m.	King Philip & Blossom Brook 2.14 sq.mi.Catch. Gals. d.p.s.m.	Av. 3 Brooks 1.08, 0.63 & 0.47 sq. mi. Catchm't Gals. d.p.s.m.
1899											
January	1 140 000	2.93	2 092 000	4.18	2 288 000	4.43	2 121 400	5.62	2 659 600	2 921 200	2 214 400
February	761 000	5.12	1 090 000	4.91	1 381 000	4.83	1 273 500	3.84	2 201 100	2 470 200	1 891 000
March	1 735 000	6.75	2 776 000	7.01	4 205 000	8.78	3 969 800	6.19	4 291 300	4 770 000	4 116 400
April	3 839 000	1.94	3 376 000	1.90	2 521 000	1.49	2 427 100	2.17	1 483 400	1 570 000	1 307 200
May	1 383 000	1.53	862 000	1.45	511 000	1.06	388 400	1.81	556 100	716 500	426 500
June	433 100	5.51	561 000	2.51	66 000	3.10	124 200	3.86	160 400	238 800	102 800
July	360 300	3.81	354 000	3.22	10 000	3.03	332 900	2.78	140 300	248 900	62 000
August	302 800	3.20	236 000	1.43	—35 000	3.66	368 000	1.64	41 900	62 500	28 200
September	289 600	4.11	250 000	3.95	94 000	5.25	278 000	7.06	177 500	265 100	91 000
October	259 800	2.72	245 000	2.69	115 000	1.79	274 200	1.94	208 400	271 500	111 200
November	405 300	1.94	430 000	2.18	304 000	3.44	262 900	2.21	320 100	396 300	201 100
December	405 900	2.03	359 000	1.78	220 000	2.04	275 600	1.26	227 700	273 000	146 000
Total		41.40		37.21		42.90		40.39			
1900											
January	487 900	4.56	796 000	4.96	794 000	5.41	482 400	4.52	788 400	706 400	654 500
February	2 393 000	8.69	4 054 000	9.14	3 800 000	10.31	2 148 000	5.12	2 034 200	2 018 000	1 924 000
March	2 359 000	6.19	3 722 000	6.35	3 654 000	5.55	2 747 000	4.02	2 376 900	2 380 500	2 292 200
April	2 686 000	2.76	1 580 000	2.58	1 350 000	2.08	1 165 000	2.10	1 104 600	1 217 900	878 100
May	1 454 000	4.34	1 382 000	4.32	1 312 000	4.86	1 467 700	5.33	1 780 600	1 942 100	1 542 700
June	574 500	3.59	578 000	2.99	316 000	2.98	516 500	1.68	276 900	350 900	200 000
July	264 400	3.20	217 000	2.42	—18 000	2.66	274 200	2.92	93 900	148 600	50 600
August	272 400	3.18	197 000	2.26	—34 000	2.39	274 300	2.02	22 700	27 300	20 000
September	219 500	3.46	127 000	3.36	65 000	4.85	283 300	3.54	67 800	96 900	36 200
October	365 600	2.90	282 000	3.83	186 000	3.63	266 800	5.00	133 800	217 000	60 900
November	849 500	6.44	875 000	5.70	663 000	4.67	374 400	3.93	356 400	423 200	257 200
December	985 100	3.15	1 570 000	2.74	1 096 000	2.52	821 000	2.46	576 500	606 800	484 400
Total		52.46		50.65		51.91		2.64			

Total		52.46		50.65		51.91		2.01				

TABLE No. 3 — *Continued.*

	Merrimac River 4451 sq. mi. Catchment.	Nashua River 119 sq. mi. Catchment. 2.2% water surface.		Sudbury River 75.2 sq. mi. Catchment. 6.5% water surface.		Stony Brook, Waltham 22 sq. mi. Catchment. 5.4% water surface.		Fall River.			
	Gals. daily per square mile.	Rainfall Inches.	Gals. d.p.s.m.	Rainfall Inches.	Gals. d.p.s.m.	Rainfall Inches.	Gals. d p.s.m.	Rainfall Inches.	North Ponds 5.45 sq. mi. Catchment. Gals. d.p.s.m.	King Philip & Blossom Brook 2.14 sq.mi.Catch. Gals. d.p.s.m.	Av. 3 Brooks 1.08, 0.63 & 0.47 sq. mi. Catchm't Gals. d.p.s.m.
1901											
January	491 200	1.75	519 000	1.82	437 000	1.42	260 000	2.22	597 600	613 300	528 900
February	356 300	1.13	356 000	1.52	300 000	1.17	200 000	0.95	310 400	353 500	273 000
March	1 384 000	5.82	2 718 000	6.57	2 755 000	6.71	1 441 200	6.54	2 504 600	2 728 300	2 327 600
April	3 779 000	9.64	4 986 000	8.60	4 204 000	6.68	3 367 300	8.39	4 179 300	4 557 600	3 937 200
May	2 267 000	7.02	2 729 000	7.23	2 954 000	7.58	2 845 100	8.05	3 566 700	4 263 100	3 074 600
June	1 092 000	1.51	985 000	1.38	753 000	7.13	744 300	1.69	1 158 100	1 353 100	969 300
July	419 800	5.06	477 000	5.71	306 000	5.44	151 700	3.18	246 700	313 300	181 700
August	645 900	4.58	512 000	4.57	424 000	4.67	286 600	2.46	97 400	156 100	61 000
September	386 100	3.10	320 000	3.30	305 000	4.01	294 700	2.51	25 700	43 000	14 100
October	599 600	3.70	647 000	2.82	412 000	2.68	255 800	3.17	213 400	304 800	86 300
November	436 900	2.43	517 000	2.90	474 000	2.78	334 200	2.18	163 200	218 600	81 800
December	1 417 000	9.36	3 234 000	2.69	2 695 000	7.38	1 423 700	8.64	1 145 800	1 352 500	1 174 400
Total		55.70		56.11		51.65		50.28			

TABLE No. 3 — *Concluded.*

SHOWING THE YEARLY AVERAGE RUN-OFF.

	Merrimac River 1451 sq. mi. Catchment. Gals. daily per square mile.	Nashua River 119 sq. mi. Catchment. 2.2% water surface. Gals. d.p.s.m.	Sudbury River 75.2 sq. mi. Catchment. 6.5% water surface. Gals. d.p.s.m.	Stony Brook, Waltham, 22 sq. mi. Catchment. 5.4% water surface. Gals. d.p.s.m.	Fall River		
					North Ponds 5.45 sq. mi. Catchment. Gals. d.p.s.m.	King Philip & Blossom Brook 2.14 sq mi. Catch. Gals. d p.s.m.	Av. 3 Brooks 1.08, 0.63 & 0.47 sq. mi. Catchm't. Gals. d.p.s.m.
1899	949 200	1 052 600	973 000	1 008 000	1 035 000	1 179 300	891 200
1900	1 076 100	1 281 700	1 082 000	901 700	794 800	838 500	700 000
1901	1 106 200	1 500 000	1 342 000	967 000	1 214 600	1 361 200	1 054 600
	1 063 000 (daily average flow).						

SHOWING THE AVERAGE RUN-OFF BY PERIODS.

Jan.–May, '99	1 771 600	2 039 200	2 181 200	2 036 000	2 238 300	2 489 600	1 997 100
June–Aug., '99	365 400	383 700	13 700	275 000	114 200	183 400	64 300
Sept.–Nov., '99	318 200	308 300	171 000	271 700	235 300	310 970	134 400
Dec., '99, –May, '00	1 596 300	1 998 000	1 855 000	1 380 900	1 385 400	1 422 900	1 239 600
June–Aug., '00	362 100	330 700	88 000	355 000	131 200	175 600	90 200
Sept.–Nov., '00	467 500	428 000	304 700	308 200	186 000	245 700	118 100
Dec., '00, –May, '01	1 540 000	2 146 000	1 958 000	1 489 100	1 955 900	2 187 100	1 771 000
June–Aug., '01	719 000	651 300	494 300	394 200	500 700	607 500	385 700
Sept.–Nov., '01	474 200	494 700	397 000	294 900	134 100	188 800	60 730

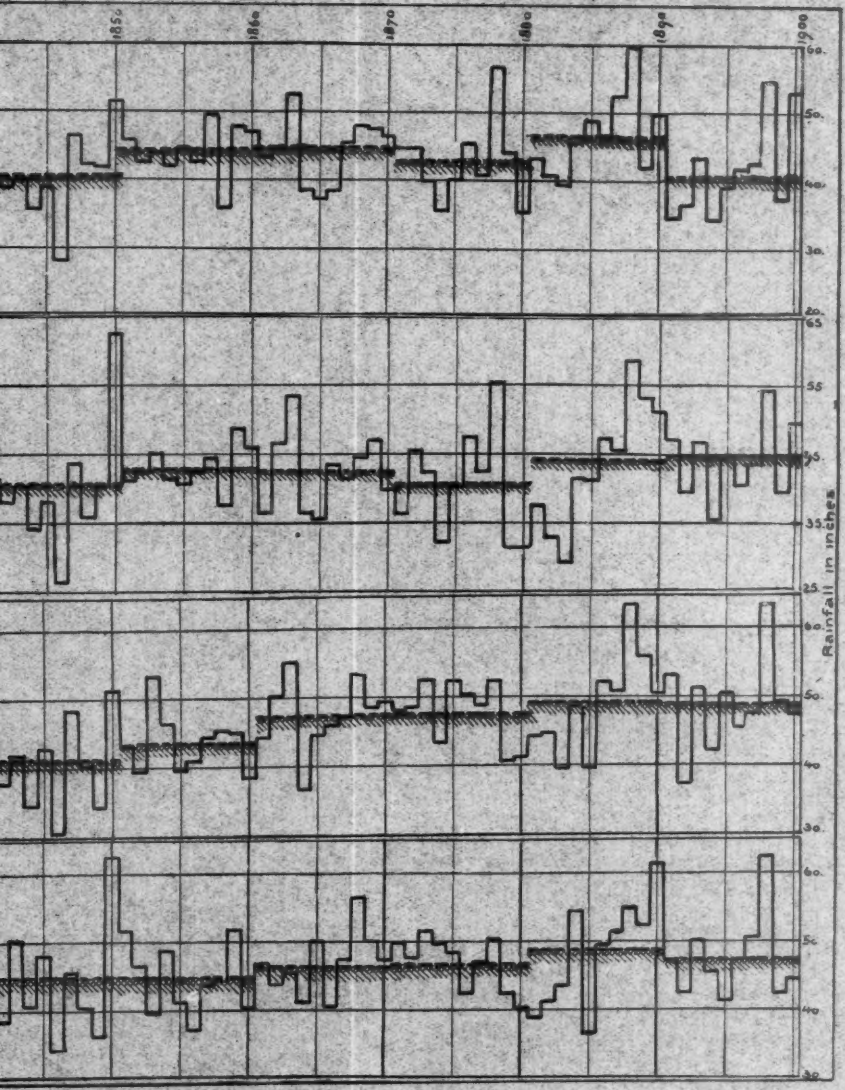
SHOWING THE AVERAGE RUN-OFF FOR DRIEST THREE MONTHS.

1899	284 000	244 000	13 700	220 400	114 200	183 400	60 400
1900	252 100	180 000	4 300	271 800	61 500	90 900	35 600
1901	414 200	436 300	341 000	231 000	95 400	139 200	52 300

SHOWING ANNUAL

PLATE I.

ANNUAL RAINFALL AND AVERAGES BY TEN YEAR PERIODS.



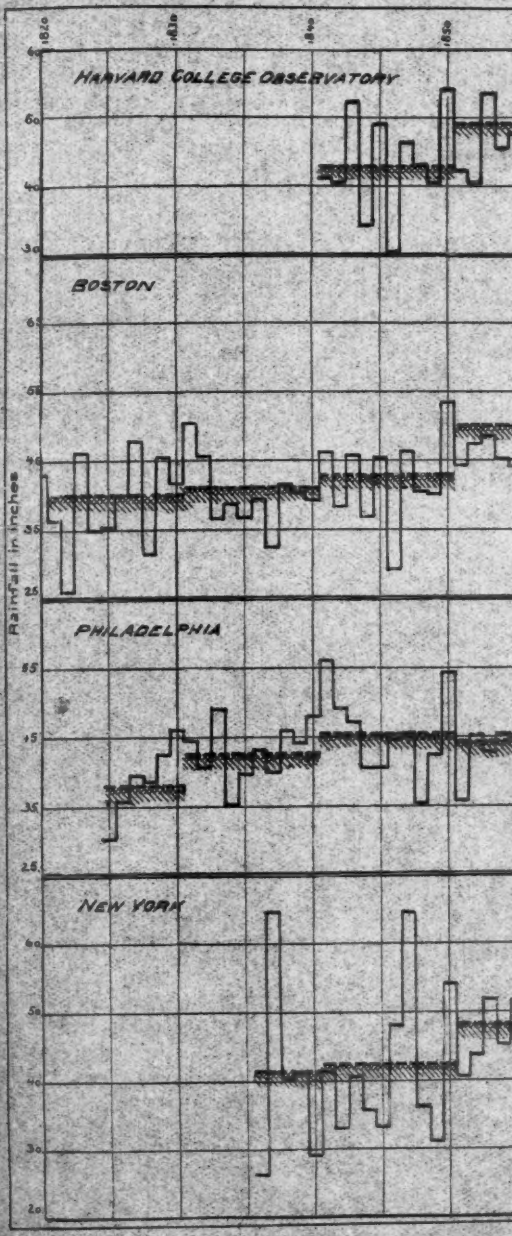
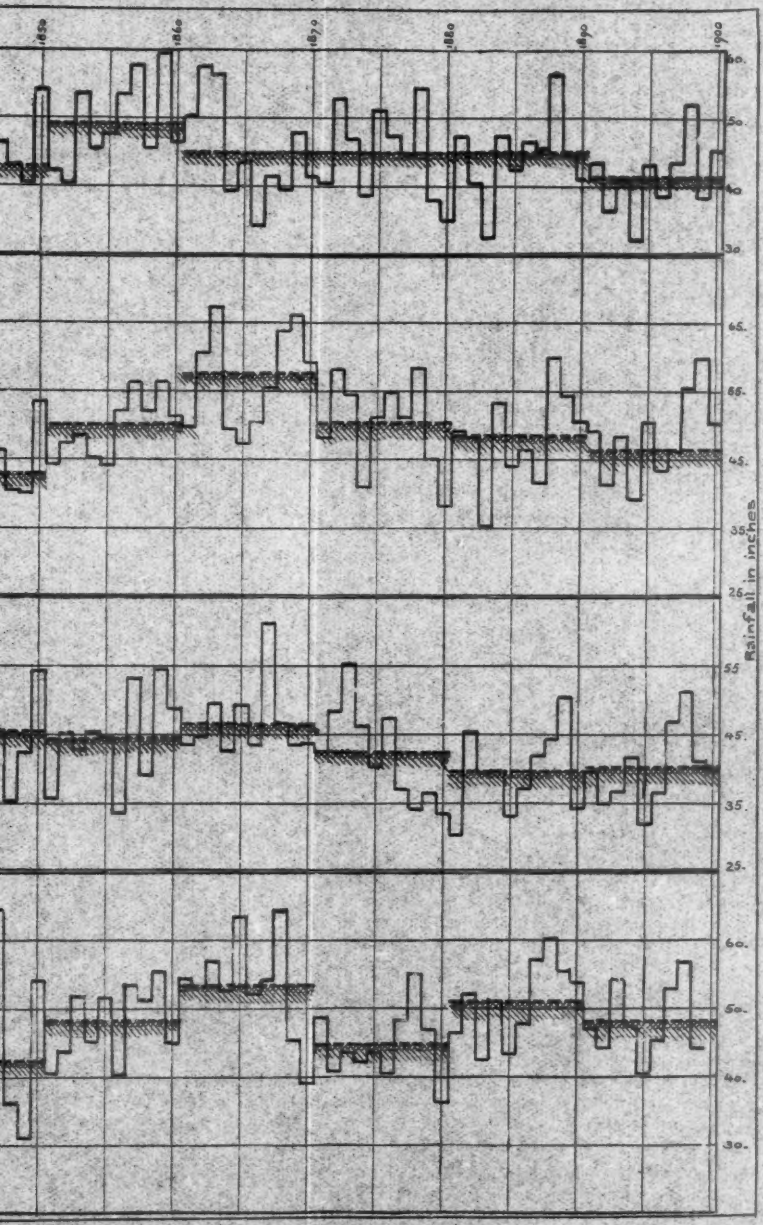
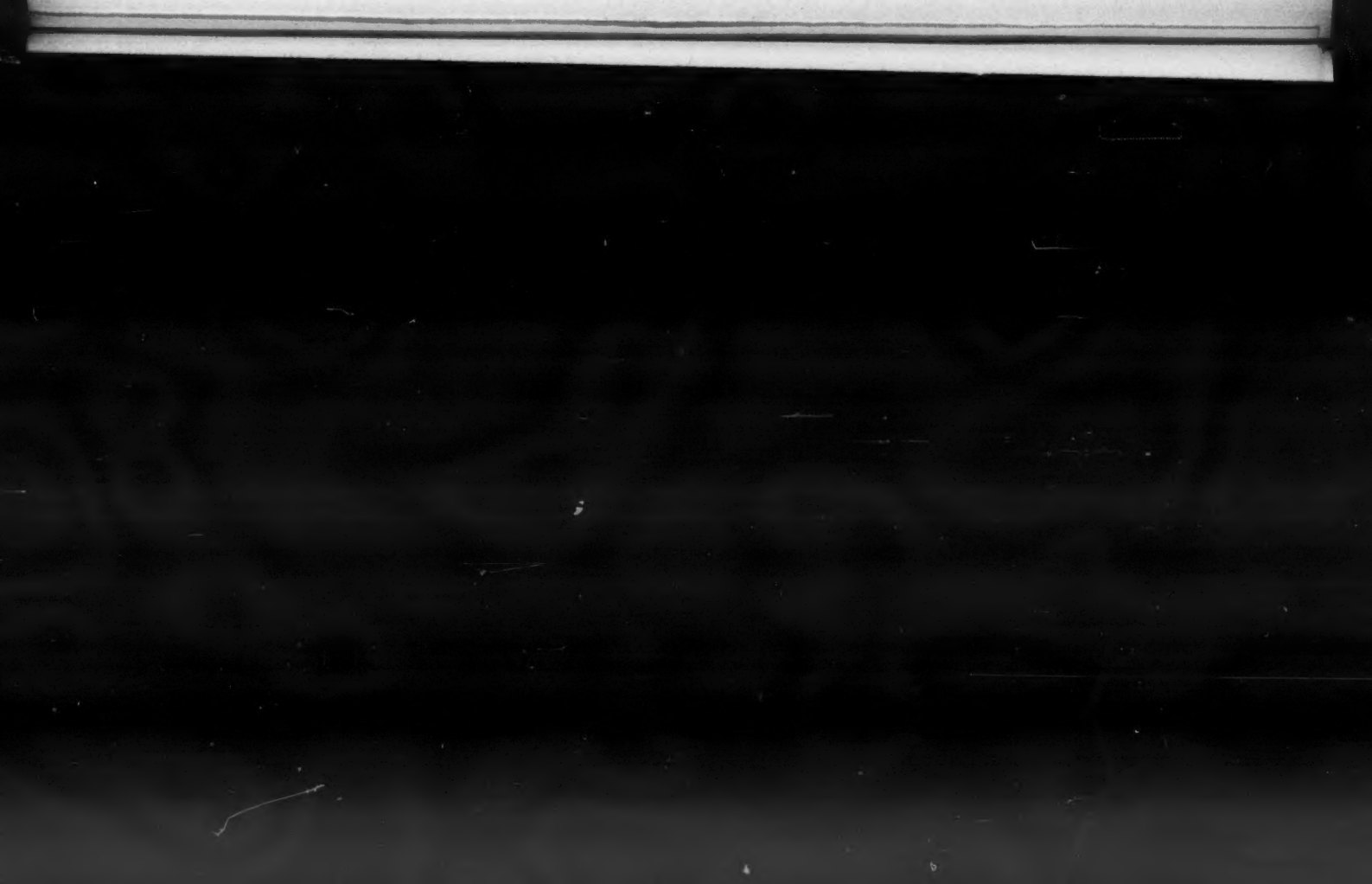

1820
1830
1840
1850
HARVARD COLLEGE OBSERVATORY
BOSTON
PHILADELPHIA
NEW YORK
Rainfall in inches

PLATE II.





This may be partly accounted for by the large percentage of water surface contained in the area in reservoirs, ponds, swamps, etc., but even after making a correction for that the amount is still much below the run-off from other areas for the same period.

It is plain that the Sudbury River is not a good dry-weather stream, and that estimates based on the flow of that stream as given in the reports would at least be conservative and safe for most areas in the vicinity.

This but illustrates the fact which can scarcely be too strongly emphasized in closing, — that most areas are to a certain extent a law unto themselves, and have certain peculiarities of their own, which should be carefully studied and compared in the light of the best data obtainable, if the best and most reliable results are to be secured.

DISCUSSION.

PROF. DWIGHT PORTER. Mr. Hastings has referred to the formula by Mr. Vermeule of New Jersey, by aid of which the evaporation from land surfaces can be computed. I have a friend here from California who tells me that in a case there with which he is familiar they applied that formula to the evaporation from land surfaces, with the result that the evaporation for the year was shown to be much more than the entire rainfall for the year, which seems to be an absurd result, and indicates, I think, the danger of putting too much confidence in a formula of this kind, especially when you apply it to a region distant from that for which it was framed.

MR. HASTINGS. I think Mr. Vermeule in his book expressly states that the formula is applicable primarily to New Jersey, but he thought it might be applicable to many other localities. I doubt, however, whether he would want to apply it to California or Arizona.

MR. RICHARD A. HALE. I have been very much interested in Mr. Hastings' paper, and I think there are a good many important facts in it. He has spoken of the different yield of large and small drainage areas, and I think that is very noticeable in the observations taken on rivers with drainage areas of different sizes. At Lawrence, on the Merrimac, which is one of the rivers

which Mr. Hastings refers to, we have a minimum yield of .3 of a cubic foot per second per square mile during the dry season; and on the Shawsheen and Spicket rivers, which are adjacent, with areas of only about 70 and 84 square miles respectively, the minimum yield is about one-third of that, or about 0.1 cubic foot per second per square mile. We are having some daily observations made on these rivers, and the difference is particularly noticeable on small streams. During the year 1900, which was an exceedingly dry period, the minimum weekly flow of the Merrimac was .3 of a cubic foot per second per square mile (average for 24 hours), and in 1883, which was one of the driest years known for a long period, the flow was .25 of a cubic foot per second per square mile, which is as low a discharge as the large river has ever given. At the same time the small streams were practically dried up, showing that the Merrimac was drawing from the underground sources of supply.

In regard to the tables to which Mr. Hastings has referred, the yields might show a little change if they were arranged according to the order of dryness in each year. On the Merrimac the period from June to August is not always the driest period, but September and October are often the driest months of the year, and November is likely to be one of the wet months. In making comparisons we find it convenient to take a series of years, arranging the months from the driest to the wettest, and taking the averages of the driest months in each year, the second driest, and so on. But Mr. Hastings' arrangements afford the means of very interesting comparisons, and are certainly of great value.

It would be of great interest if more records could be kept in regard to the flow of small streams, and, where there are pumping stations and dams, records of what is pumped and what runs to waste would indicate the yield and the run-off of the streams. It is a matter which can be arranged for very readily where there are dams and overflows. Records of this sort are very valuable, and Mr. Newell, the Chief Engineer of the Hydrographic Survey, is making a very important compilation of such records. The data are of great benefit in increasing our general knowledge of the flow of streams.

METER RATES.

BY FREEMAN C. COFFIN, CIVIL AND HYDRAULIC ENGINEER,
BOSTON, MASS.

[*Read January* 13, 1904.]

Engineers and water-works officials are, I think, becoming more and more impressed with the belief that the general use of meters is desirable, and that the method of collecting revenue by means of fixture rates, which is now almost universal, will some time become obsolete and water meters become as universal as gas meters.

There is at present some popular prejudice against their use, people believing that with them they will be restricted in the use of water, or that their bills will be larger.

I do not propose to offer any arguments for the use of meters at this time. We have had some such, notably an excellent one in the recent paper of Mr. J. Herbert Shedd. The results in every city or town which has adopted meters to a considerable extent are substantial arguments for their use.

What I wish to do now is to point out the fact that, viewed as a scientific method of assessing water rates, the meter system, in so far as a basis of rates is concerned, is in almost as chaotic a state as the fixture rate system itself. Several years ago in a paper which the present writer read before this Association, he made the following remarks:

"If the rates in any system are not satisfactory, being either too high or too low, the problem of their adjustment to the requirements of expenditure is one of which it may not be too much to say that no solution has been advanced that considers the conditions of the problem.

"The same may be said of fixing rates for new works. The only method that the writer is cognizant of is that of comparison, and comparison of rates only and not of conditions as well. To collect the schedules of several systems and construct rates from these without regard to such factors as cost of construction per capita, consumption of water per capita, cost of water per million

or thousand gallons, etc., is not a rational method, and gives no assurance that the revenue will be approximately equal to the requirements; yet many if not all rates are fixed in this way.

"There can hardly be a theory advanced for the adjustment of fixture rates. It is possible that with the sale of water by measurement, rates could be devised that would bear some relation to the revenue required. This would, however, be difficult and uncertain until more data upon the subject are available."

These remarks are as true to-day as they were then. When meters are to be introduced to a large extent in any water-works system, some system of charges must be devised.

The object should be to so arrange these charges as to secure just about enough revenue each year to meet all of the expenses of maintenance that are not met from sources other than water consumers, so that the minimum charge shall allow the class paying the lowest rate under meter regulations an abundance of water for reasonable use, but none for waste; also arranged so that people with large houses and a great number of fixtures cannot by exceedingly close calculation escape with paying the equivalent of one faucet rate, and above all to encourage the prevention of leaking fixtures and the accompanying excessive per capita consumption of water.

If water-works officials wish to arrange suitable meter rates, what have they to guide them, where can they look for information? If they ask their consulting engineer for advice, what can he answer them? where can he go for data on the following points?

Namely: How much shall be the charge per thousand gallons? What shall be the minimum annual charge? To what class of service shall it apply? How much water shall be allowed for the minimum rate? If the minimum rate is adjusted for the single-faucet class of consumers, will the revenue from large houses with many fixtures be commensurate with the comfort and luxury of the service furnished? If not, how can this case be met? How can meter rates be arranged in a place with a large summer and small permanent population?

The above are all practical questions. Who can answer them with any degree of confidence?

The rates must be arranged, however, so that on the one hand

the revenue shall be sufficient, and on the other that the charges to careful consumers shall be equitable and not more burdensome than the old fixture charges.

There must be an accumulation of valuable data upon all or many of these points in the water offices of those municipalities which have a considerable proportion of their services metered, but no one engineer or no one board of water commissioners can collect and digest them.

In view of the foregoing, and in order to bring this matter up for discussion, I make the following motion. It is not pressed for immediate action, but it is hoped that before long this Association, following its past record in undertaking the consideration of problems that call for co-operative action, will carry out the suggestion in some form.

Moved: That a committee of this Association be appointed to consider the question of meter rates for water service, collect and digest information, and submit to the Association a schedule or schedules designed to meet various conditions of a metered service, or a basis upon which such schedules can be arranged; that this committee consist of five members; that the committee be authorized to expend a sum not exceeding fifty dollars in printing, postage, and other necessary expenses involved in the collection of data.

THAWING FROZEN SERVICE BOXES, PIPES, ETC.

TOPICAL DISCUSSION.

[*January* 13, 1904.]

Pres. Edwin C. Brooks. I may mention one little thing in my recent experience. It is very simple, perhaps trivial, and it may be of no importance; possibly many people are doing the same th ng every day; but during this cold spell, when shutting off water from houses was a constant occupation, we found that a good many covers of standpipes or service boxes were frozen down, and the men had to run into the neighboring houses after hot water to thaw them out so they could get the covers off. It happened to occur to one man that a little benzine, poured on to the top of the cover and lighted, would be a good thing. It was tried and the consequence is that we don't have to run after hot water any more. A bottle of benzine holding a quart will be sufficient for perhaps fifty service-box covers. It does the work perfectly, and it isn't necessary to annoy any householder, — and you know that oftentimes we may have to go into three or four houses before we can get a pail of hot water. Now, as I say, that is a little thing, something which everybody ought to have thought of, but how many have thought of it?

Mr. Joseph E. Beals. Will kerosene do instead of benzine?

The President. Kerosene does not light readily, but a little naphtha does very nicely. You know that the ordinary Morgan box has a little receptacle around the screw, and by the time the benzine has burned out the cover is hot and the thing comes up without any trouble. And even the old-fashioned boxes where the cap slips down over, which are particularly annoying to get up in brickwork, yield to the treatment very readily.

Mr. J. C. Hammond, Jr. Several years ago I read in one of the water-works journals about the use of lime for thawing. We had a 3-inch branch running into a court with only one or two service pipes on it, and it froze,— the branch and the whole business. We went to work and dug down, opening a hole perhaps two feet deep, when I happened to think of what I had read.

We were close to a lumber yard and I got a barrel of lime and dumped it into the hole and threw some water on it; and the next morning when we came there the pipe was thawed out and the ground was all softened.

Mr. Hardy, superintendent at Holyoke, can tell you how he thaws out a frozen pipe without digging.

MR. J. D. HARDY. We have a boiler on wheels which we use for thawing out pipes. We can draw it around the city anywhere with one horse, and we connect a hose pipe to the boiler, and on the end of the hose we have, say, a ¾-inch pipe about six feet long, with handles on it, and we let steam on under from 50 to 60 pounds pressure, start it down into the ground, and it will go as readily as you can imagine. It will go right down. We put it down about where we think the pipe is frozen, and let it " cook " there, as we call it, that is, let the steam be on for a few minutes; and if that doesn't thaw it out we move along on the line. We find it a very excellent way of thawing out pipes and very handy for many purposes.

MR. CHARLES K. WALKER. I have been thinking of this thing and have been trying to find somebody who would make me a small gasolene boiler which two men could put into a sleigh and carry around to thaw out hydrants and service pipes, but I haven't been able to get anybody yet. Such a machine, weighing, say, from 200 to 250 pounds, would be very handy. I have a boiler, but it takes two horses to pull it, and it seems to me that a machine might be made which could be run with kerosene or gasolene or something of the kind, and would be light and easily handled, and which would do all the business. Now if the gentleman from Holyoke has got something which weighs more than 250 pounds that is one thing, but if he has got a light one I would like to talk with him.

MR. HARDY. Ours is very easily handled; a horse will take it around anywhere without any trouble. It is light enough so that one horse can pull it.

MR. WALKER. Of course you can't go into a cellar with that and thaw out into the street. It is going to freeze eight or ten feet deep in Manchester this winter if it keeps on, and the service pipes are likely to get caught.

MR. HARDY. We have another machine that we use in going

into cellars, with a block-tin pipe which we can run out if we choose. But when we do that the service is liable to freeze up again, unless the water is kept running continually. But with this boiler, when you once thaw out a pipe or a hydrant it is done for the winter. There is no probability of the frost going down again, — that is, we have never found it to happen. It is a very convenient thing to put down by the side of a hydrant; it can be done very quickly, and it doesn't injure the hydrant. I should like to have any of you gentlemen come up to Holyoke and see it.

MR. FRANK L. FULLER. Do you make a hole with a bar for your steam nozzle?

MR. HARDY. No, it goes right down itself; you don't have to make any hole.

MR. FULLER. The pressure of the steam will make a hole?

MR. HARDY. It will make a hole, clear everything right out in front of it,— any small stone or anything of that kind. It will go down in the time I have been talking with you. At least it does at Holyoke.

THE PRESIDENT. With regard to the use of lime, a few years ago I happened to be up in Waltham and I noticed they were putting in a siding on an electric road there. There must have been nearly two feet of frost in the ground. It was a macadamized street, and I saw them scatter along on the line for their digging several barrels of lime, which they then covered up with a load of manure and wet down. The next day the ground was in perfect shape for digging, without any frost, and the siding was put in and everything finished up in good shape.

The plumbers, who, as you all know, have had a particularly good harvest lately, have taken up the idea of a small tubular boiler about 12 inches high and 10 or 12 inches in diameter, with three or four 1-inch tubes put through from head to head, and a little crude safety-valve and stopcock on the top of it. That is set on a plumber's furnace. They go into a cellar with it and in a very few minutes will have steam enough so they can thaw out a pipe very rapidly. They have a $\frac{3}{8}$- or $\frac{1}{2}$-inch rubber hose with a piece of block-tin pipe on the end of it, and it is very effective indeed. I think possibly that might be elaborated so as to make a very convenient tool for water-works people to use. I think a combination might be made with some of the larger

burners that they have for melting, and possibly they could use kerosene in place of naphtha if the naphtha was thought to be too dangerous.

MR. GEORGE E. WINSLOW. I will tell a little experience I had quite a number of years ago with services. I wanted a boiler so that I could get steam or hot water to thaw out services, but I didn't have the privilege of getting it, and so I was forced to use hot water when I could find any. But in some cases it was rather inconvenient to get hot water, and after I had this experience which I am about to relate I didn't bother any more to try to get it. I had a service which ran down a lane and turned at a right angle into a house, and that was frozen for its whole length. The distance from the angle to the street main was about eighty feet. I had to dig down to get at the pipe, and then I used a block-tin pipe, the same as you all do, and used cold water with a Johnson pump. I think the friction of the water against the ice wore it away, but at any rate I had no trouble in freeing the pipe with cold water, and I never bothered to get hot water after that.

THE PRESIDENT. I should think, Brother Winslow, that with the temperature down in the neighborhood of zero the cold water would become ice in the hole in which you were working before you had gone along a great way.

MR. S. A. AGNEW. The great trouble I have always found in thawing out a service pipe in that way has been that it would freeze up immediately afterwards. Mr. Hardy's method seems to be the best in that it warms the ground down under the surface and the pipe doesn't freeze again. But where a pipe is thawed out one day and we have a cold night following, the pipe will freeze up again unless the water is allowed to run. That is the great trouble in thawing the pipe out in the ordinary way. By Mr. Hardy's method the ground is warmed, and the probability is that the pipe will not freeze again during the winter unless there is another unusually severe cold spell.

MR. LEWIS M. BANCROFT. Mr. President, I have a small boiler which I think perhaps will answer Mr. Walker's purpose; or rather, one like it, for I don't want to give him mine. It is about a foot in diameter and about three feet high, an upright boiler. It only has one tube through the center. I place it over

a charcoal fire, have the fire pot of the same size, and I can get up 25 or 30 pounds of steam, and we use it through a block-tin pipe.

MR. ROBERT S. WESTON. There is a boiler made for chemical laboratories in sizes varying from about 100 to 300 pounds in weight. It has one tube and is heated either by a charcoal fire or a gas burner, and I should think it would answer for this purpose very well.

MR. WALKER. I want one with more than one tube. I want something which will make steam faster than any one-tube affair. I think Mr. Bancroft is all right, and if his boiler had three or four tubes I think I would take it. I have tried to have some of the boiler folks get up something for me, but they don't seem to know how to do it. I have a boiler which I like first rate, but it takes a couple of horses to pull it around. It is big enough to thaw out a whole city in a little while. It is 10 horse-power and will do quite a lot of business. But I thought there might be something which we could take around in a sleigh, which would weigh 200 or 250 pounds, a regular boiler with five or six tubes. That is my idea of the thing, and I would like to have the President tell me before I go home what I had better do.

THE PRESIDENT. I think you had better get an automobile boiler, and I wouldn't use charcoal or coal at all, but I would have a good efficient kerosene burner, or two or three of them, if necessary.

MR. WALKER. Where can I get such a thing as that?

THE PRESIDENT. I think you ought to consult the advertising pages of the JOURNAL. (Laughter.)

MR. WALKER. That is pretty good; I like that idea first rate.

THE PRESIDENT. I might volunteer the information that the Roberts Boiler Works in Cambridgeport are building automobile boilers all the time.

MR. WALKER. I am afraid of automobiles. (Laughter.) I don't like the sound of that word. However, if I could have the same kind of a boiler under another name it might do. (Laughter.)

MR. SULLIVAN. The boiler that Mr. Hardy speaks of is about two feet in diameter and about four feet and a half high. It is on wheels and he can take it anywhere he wants to and can use it for a great many different things when occasions arise. One

horse can haul it all right, and I think it is a good thing to have on any works.

Mr. George A. Stacy. As near as I can make out, what Mr. Walker wants, in the first place, is a boiler that will act quickly, and it seems to me that an automobile boiler is a good thing in that respect, for it is a quick steamer. One trouble about it, however, is that you have got to keep pumping water into it if it is generating steam rapidly, for if you don't do that you will burn it out. My idea is to have a drum above the boiler and connected with the top and bottom of it, and then by careful management you would never run the boiler dry. It would be practically a double boiler; you could take your steam out of the top connection, and you might have four good burners. I should prefer kerosene burners. You could put that into a sleigh, and two men could handle it. That is something I have been thinking of and trying to get up, and I don't know of anything, so far as the boiler is concerned, which for safety and efficiency and quick action will beat an automobile boiler, and that can be readily obtained. Now, if you can have your receiver or your drum to insure that you are going to have water in the boiler under ordinary conditions, so that you can trust a man with it, I don't see why you can't light your fire and put it in your pung and have everything all ready when you get to the place where you want to use it. Then if you want to take it down into a cellar you can do so, or if you want to run up by the side of a hydrant you can do that, and by the time you have got there you have steam enough and water enough to do the work, and when you get through you can put out the fire. Of course it is necessary to have some sort of a shield so that when you go out on a cold, windy day you can keep your fire burning, and if you do that I don't see any difficulty about getting up steam and having something handy to work with. Of course if you have got to do some more extensive work and thaw out the ground you need an eight or ten horse-power boiler; but for something to use on the spur of the moment, in fifteen or twenty minutes, something which you can put into your team and light the fire and be all ready to go to work with by the time you arrive at the place, I don't know of anything better than an automobile boiler. It is perfectly safe if you have a pop safety-valve on it. One of these boilers will stand 400 pounds pressure

and you don't want more than a sixteenth part of that in order to do your work. Put your pop in so it will blow, and you are all right. I think there would be no trouble about a man handling it.

THE PRESIDENT. It would seem to me as though the drum Mr. Stacy speaks of would be rather a superfluity. I think the ordinary automobile boiler will hold water enough so that it will be perfectly safe from burning for half an hour.

MR. STACY. If you were going to use it, Mr. President, I should say it would be perfectly safe at any time, but I am providing so that men can use it who are not much acquainted with steam engineering.

THE PRESIDENT. If you have your drum and your bottom boiler filled with water it is true that you have more water, but it is also true that you will have to wait longer to get up steam; and your man is relying on having so much more water and is consequently going to presume that it will last so much longer; so I think the danger would be equally as great in one case as the other. I think a little gray matter is necessary to make the thing work, anyway.

MR. STACY. That may be true, but it seemed to me that a drum would be of value as a preventive against carelessness. It wouldn't be necessary for me, if I was going to handle it, to have a drum, but I shouldn't want to send an ordinary man out with it without one. If I did, I should expect to have to calk the tubes when he came back with it.

FREEZING OF HOUSE METERS.

TOPICAL DISCUSSION.

[*February* 10, 1904.]

PRES. EDWIN C. BROOKS. I should like to call your attention, gentlemen, to the trouble which some of us have had from the freezing of meters during this cold weather. I had hoped that Mr. Perkins, of Watertown, could remain long enough to relate to you the experience which he has had during this cold spell, but he was obliged to leave. Before going, however, he told me that they had not had a single meter freeze in their outside meter boxes; and, considering the fact that those meters are set so near the surface in earthen pipes, that seemed to me very remarkable. He told me that all the trouble he has had has been with meters in houses; and I may say that that has also been our experience in Cambridge. Now I think we have all got to consider seriously the question of setting meters outside. I find that houses are sometimes vacated where meters are set, the families go away and no notice is given, and the first thing we know somebody throws a snowball through a cellar window which unfortunately happens to be located right over the meter, and the meter freezes up.

I should like to hear the experience of some of the other members in regard to this very important question.

MR. E. W. KENT.* I have no meters set outside in earthenware pipes; mine are all inside. I have about 2 200 meters, and up to two weeks ago Saturday night we had removed 101 that were frozen.

MR. HORACE G. HOLDEN.† All our services run into the houses below the foundations, usually a foot below the cellar bottom. We set our meters at this depth in a box, and they are covered up. We have somewhere about 600 meters, and I think there haven't been over half a dozen, or about 1 per cent. of the meters, that have been frozen; and all those that have been frozen have been where somebody has removed the covers. What we use for a box is made out of old cement lined pipe, about 12 or 15 inches

* Superintendent of Water Works, Woonsocket, R. I.
† Superintendent of Water Works, Nashua, N. H.

long, with a wooden cover. This we set just below the cellar bottom, right over the meter. Where there is any danger of its freezing we cover it up with bagging, because we own all the meters ourselves; the occupant or householder never owns the meter; they are all owned by the company.

MR. ROBERT J. THOMAS.* Out of 7 200 meters we have had about 300 frozen this winter. They were all meters which were set in cellars.

THE PRESIDENT. I should like to hear from Mr. King.

MR. GEORGE A. KING.† Most of our meters are set in cellars.

THE PRESIDENT. Have many of them been frozen?

MR. KING. Yes; I couldn't tell the number though.

THE PRESIDENT. What has Mr. Chace got to say?

MR. GEORGE F. CHACE. Nothing uncommon, Mr. President. Like other people, I have had some frozen meters.

THE PRESIDENT. Can Mr. Robertson tell us anything about Fall River?

MR. W. W. ROBERTSON. I should say our experience has been similar to that of Mr. Thomas. We have about the same number of meters, 7 200, and we have had about 300 frozen, according to my best recollection, although it may be a few less or a few more.

THE PRESIDENT. We should like to hear from Mr. Martin, of Springfield. I suppose it has been pretty cold out there.

MR. A. E. MARTIN. We have had some cold weather, Mr. President, and I think out of about 3 500 meters we have had 60 frozen, all of them in cellars.

MR. FRANK L. FULLER. We have 911 meters in Wellesley, and 47 of them have frozen. So far as I know they were all in cellars.

MR. LEWIS M. BANCROFT. We have about 1 050 in Reading. About 75 of those are in boxes in the streets. We have had no trouble with meters in those boxes, but we have had 57 freeze in cellars.

MR. M. F. COLLINS.‡ We have had about 150 meters frozen this winter, all in cellars; no outside meter has frozen. In all, we have 5 603 meters.

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* Superintendent of Water Works, Lowell, Mass.
† Superintendent of Water Works, Taunton, Mass.
‡ Superintendent of Water Works, Lawrence, Mass.

NOTES ON THE CONSTRUCTION OF A STORAGE RESERVOIR.

BY W. H. RICHARDS, ENGINEER, NEW LONDON, CONN.

[*Read December* 9, 1903.]

In the following paper no effort is made to completely describe the whole work, but only such portions of the construction as are somewhat unusual.

Owing to the threatened shortage of supply occasioned by the scanty rainfall of the fall and winter of 1900–1901, it became necessary to increase the supply of water for the city of New London, Conn., by the construction of an additional storage reservoir. Work was begun in August, 1901, and the reservoir was completed in the spring of 1903.

As constructed, the reservoir has a drainage area of 2.7 square miles, covers an area of 46.5 acres, and has a capacity of 170 000-000 gallons, it being so arranged that any surplus can be stored in the main storage reservoir at a lower level.

The reservoir, Plate I, is situated in the valley of a large brook surrounded by heavily wooded hills, the immediate banks of the basin being gravel and sand interspersed with granite bowlders. The sides of the basin were thoroughly grubbed and all soil removed down to clean gravel, but the bottom of the basin being composed of mud from 4 to 6 feet deep, it was covered with sand to a thickness of about 1 foot, after removing all stumps and projecting roots. As the water stands about 20 feet deep over this area and in no place comes in immediate contact with the muck or decayed vegetable matter, it is difficult to see how any considerable deterioration of the water can take place. The writer is aware that it is usual to expend large sums of money in removing the last vestige of decomposed vegetation, but, inasmuch as most large reservoir bottoms will be covered with such a deposit in a few years, and as on a bottom covered with sand the water does not come in direct contact with the decomposed vegetation or muck, and contamination by particles in suspen-

sion is thereby avoided, may it not be that the capacity of the muck to contaminate by solution has practically ceased and that large expenditures for its removal are unwarranted?

At the upper end of the basin a shallow arm was cut off from

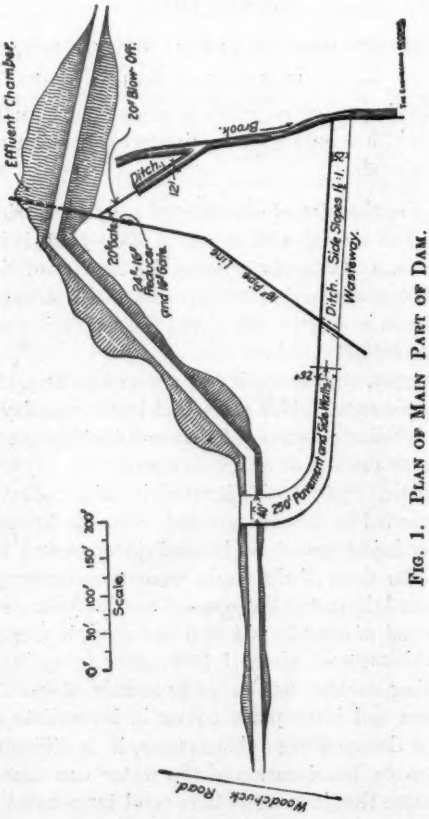

FIG. 1. PLAN OF MAIN PART OF DAM.

the main lake by a so-called filter dam. Above this dam no effort was made to grub or cover the surface, only stumps and roots being cut off close to the ground. The filter dam consists simply of a bank of gravel about 400 feet long, 20 feet high, and 10 feet wide

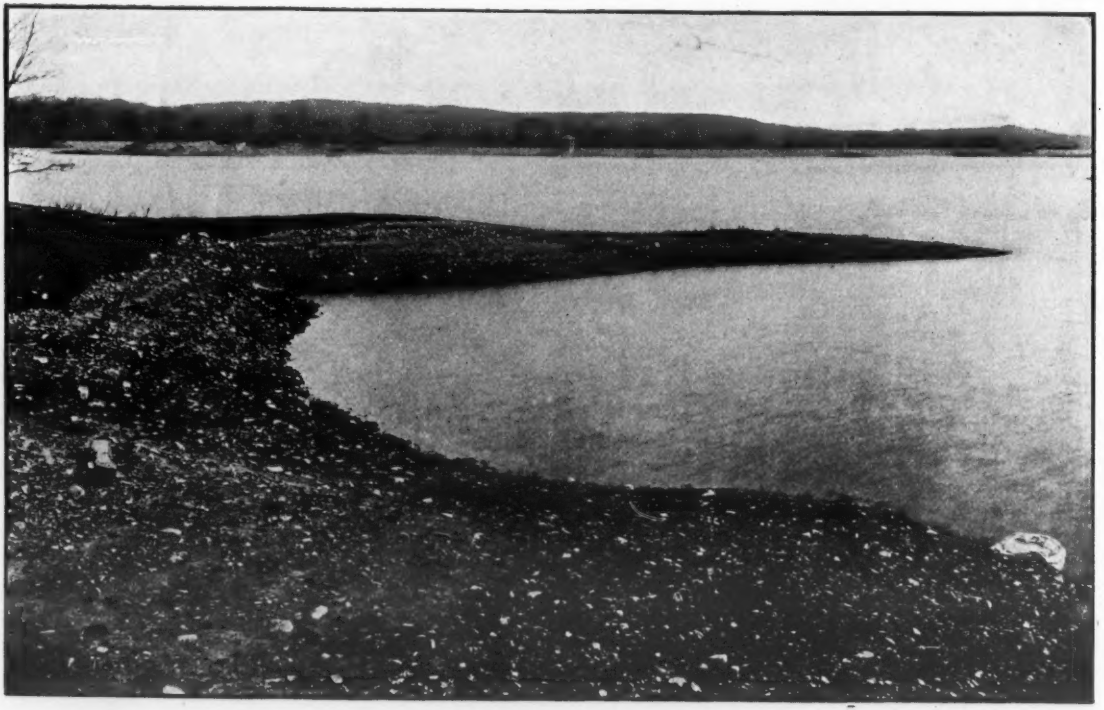

PLATE I.

BARNS RESERVOIR, LOOKING SOUTHEAST.

on top. The water behind this bank is supposed to filter through it when the reservoir is drawn down.

In this connection it may be interesting to note that a similar construction in the lower reservoir has been in use about thirty years, with excellent results. An analysis made in 1887 showed a great diminution in color and in organic and volatile matter after passing through the dam.

The main dam consists of an earth and gravel embankment with concrete core wall about 1 200 feet long, the embankment varying in height from 10 to 25 feet above the natural surface. In locating this dam advantage was taken of a series of low hillocks, making the plan somewhat irregular but effecting a great saving in embankment (Fig. 1). Gravel and sand of various degrees of firmness, going to an unknown depth, underlie the entire site of the dam.

The concrete core wall was located close to the inner slope of the dam, the greatest care being taken to make it impervious; and as no dependence was placed on it to resist strains or add weight to the dam, it was made but 3 feet thick up to within 18 feet of the top, where it begins to batter, and at the top is 1½ feet thick. This location gave room for the largest cross-section and consequent weight of embankment below the core wall, where needed. Views of the dam under construction are given in Plate II.

The concrete was formed of 1 part Portland cement and 9 parts of gravel and sand used as taken from the pit. This material from the pit, which was located in close proximity to the dam, was carefully examined at frequent intervals and the material kept as near the proportion of 3 sand, 2 fine gravel, and 4 stone not larger than 2½ inches, as possible. The concrete was mixed very wet, 1½ to 2 parts of water being used to 10 parts of stock, and was built between forms, the inner surface being plastered and washed after the removal of the forms. It was found that mixing the concrete wet vastly increased its density or lack of porosity, as when thrown between the forms the water rose to the top and ran off or evaporated. The concrete was built up in layers of about 2 to 3 feet, a triangular wooden block being placed in the center of the top of each layer to form a groove to dovetail with the next layer. The embankment on the outside of the wall was composed of sand and gravel, the finer material being placed next the core

wall and puddled, the coarse material outside this. This construction was adopted that the core wall might have as firm and

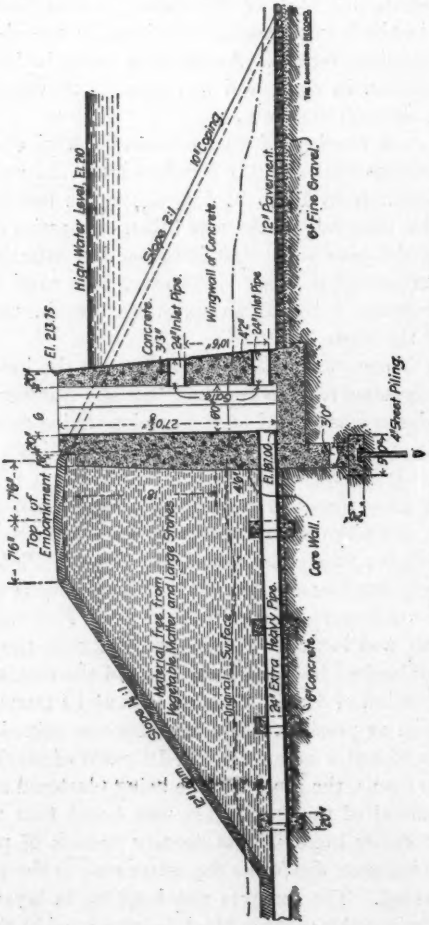

FIG. 2. SECTION THROUGH EFFLUENT CHAMBER.

uniform a backing as possible, and that in case of leakage the water might find its way through without destroying the embankment.

FIG. 1. PART OF UP-STREAM FACE OF DAM DURING CONSTRUCTION.

FIG. 2. PART OF DOWN-STREAM FACE DURING CONSTRUCTION.

The embankment in front of the wall was composed of loam thoroughly rolled, no clay being available. The inside slope was paved with 12-inch paving, the outside slope was finished with loam and seeded. The slopes were 2 to 1 inside and 1½ to 1 outside.

In a portion of the core-wall trench a fine sand was encountered at a depth of 34 feet. Into this, 4-inch grooved and splined sheeting was driven to an additional depth of 25 feet, the core wall being built upon it. A portion of this sheeting was driven with a steam rock drill, having a light hammer substituted for the drill, the whole fastened to a frame and lowered into the trench, but as the light construction of the drill caused it to break frequently, an ordinary pile-driver giving very light blows was finally substituted; but the experience proved that with a sufficiently strong machine the rock drill has great advantages and economy over the ordinary pile-driver for driving sheet piles in a trench.

The gate-chamber, Fig. 2, was built of concrete similar to that of the core wall and surmounted by a stone gate-house. The spillway and wing walls were of granite. The spillway, Plate III, is 40 feet wide, or 15.8 feet for each square mile of watershed. The greatest observed depth of water on the overflow has been 6 inches. The water falls over the spillway with a perpendicular drop of 3 feet, and then runs down a paved slope of 12 in 100 into the brook below the dam.

Water is admitted into the chamber through two 24-inch sluice-gates and flows through a 16-inch and 20-inch main a distance of 3 miles to the main storage reservoir.

The cost of the work was greatly increased by the difficulties of transportation, as all material used, including 1 000 tons of pipe and nearly 4 000 barrels of cement, had to be carted over 10 miles of rough, hilly country.

The contract for the work was completed by the C. H. Eglee Co. in a very satisfactory manner, under the direction of R. W. Chaffee, Assistant Engineer.

DISCUSSION.

MR. FRANK L. FULLER. I should like to ask Mr. Richards to describe a little more in detail the driving of this sheet piling by the steam drill.

MR. RICHARDS. The sheet piling was 4 inches thick, usually about 8 inches wide, grooved and splined. It was driven between two waling pieces laid lengthwise of the trench, and as the trench was about 35 feet deep and in very fine sand at the bottom, it was, of course, rather difficult to use an ordinary pile-driver for the reason that its operation would shake the sides of the trench so they would be liable to cave in; and, furthermore, every brace would have to be moved when you moved your pile-driver along, and there were a good many of them in a 35-foot trench. So we tried a steam drill, first with a hammer we made ourselves, and afterwards with one which was made by the company. So long as the drill lasted we were very successful in driving the piles, — that is, the strokes of the hammer were so near together that the pile didn't have time to stick, or, in other words, the sand didn't have time to settle around it, but, having once started, the pile kept going. The drill, of course, was made for a different purpose, and it broke continually, so we finally had to give it up and use the ordinary pile-driver. I think a more strongly made drill would work very nicely, and I understand that they make one now especially for driving piles.

MR. FULLER. How heavy was the hammer you used?

MR. RICHARDS. My impression is it wasn't more than 10 or 15 pounds; it was very light.

A MEMBER. I believe Mr. Richards has some very interesting information with reference to an impulse wheel and rotary pump, and I should like to have him describe that to us in a few words, if he will.

MR. RICHARDS. I am not quite ready to describe the pumping station, as it is not finished yet, and I don't know exactly what it will do. I should prefer to wait until I have tried it. However, I can say that we were very peculiarly situated in having a water supply of such a quality that we couldn't use it for anything else but power, so we use it for power to pump to our high service. We have about 120 feet head, and with that head we use a jet impulse wheel, a Pelton wheel, in one case coupled directly to a rotary pump. We have another wheel which is coupled on to an ordinary triplex pump. So far it appears to work very nicely. It pumps against something like 60 pounds. When it is tested I shall be pleased to describe it.

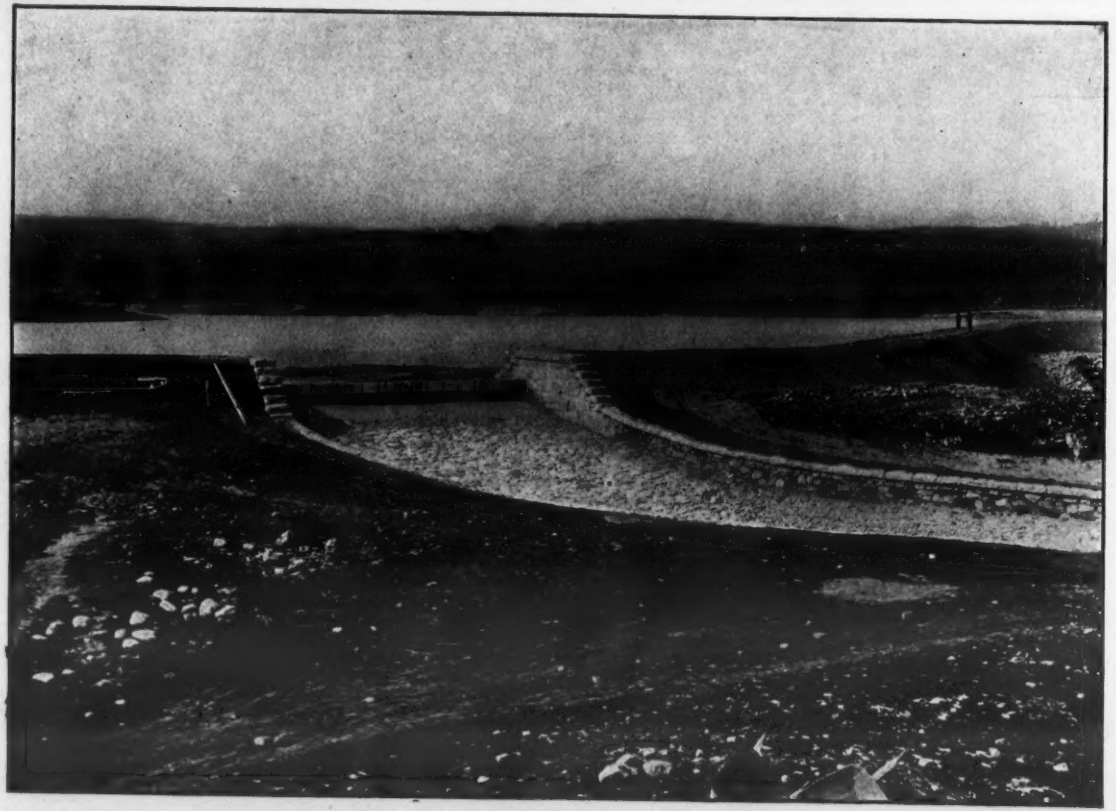

PLATE III.

BARNS RESERVOIR, LOOKING NORTH FROM SPILLWAY.

PROCEEDINGS.

December Meeting.

Hotel Brunswick,
Boston, December 9, 1903.

President Charles K. Walker in the chair; Willard Kent, Secretary.

The following members and guests were in attendance:

Members.

S. A. Agnew, F. E. Appleton, E. W. Bailey, C. H. Baldwin, L. M. Bancroft, J. E. Beals, J. F. Bigelow, F. D. Berry, George Bowers, E. C. Brooks, G. A. P. Bucknam, E. W. Bush, L. Z. Carpenter, George Cassell, G. F. Chace, C. E. Chandler, R. C. P. Coggeshall, M. F. Collins, H. A. Cook, G. E. Crowell, A. W. Cuddeback, C. E. Davis, J. H. Flynn, F. L. Fuller, J. C. Gilbert, A. S. Glover, F. W. Gow, W. R. Groce, R. A. Hale, F. E. Hall, J. O. Hall, D. A. Harris, L. M. Hastings, V. C. Hastings, T. G. Hazard, Jr., D. A. Heffernan, H. G. Holden, J. L. Howard, A. F. Hill, W. E. Johnson, J. A. Jones, J. Wm. Kay, Willard Kent, G. A. King, G. A. Kimball, E. S. Larned, J. W. Locke, H. V. Macksey, N. A. McMillen, D. A. Makepeace, A. E. Martin, W. E. Maybury, F. E. Merrill, F. L. Northrop, E. M. Peck, Dwight Porter, J. B. Putnam, C. W. Sherman, J. W. Smith, G. H. Snell, H. W. Spooner, W. F. Sullivan, L. A. Taylor, R. J. Thomas, William H. Thomas, J. L. Tighe, D. N. Tower, W. H. Vaughn, C. K. Walker, W. J. Wetherbee, F. I. Winslow, G. E. Winslow. — 72.

Associates.

Allis-Chalmers Co., by C. W. Houghton; Harold L. Bond & Co., by H. L. Bond; Builders Iron Foundry, by Frederick N. Connet; Chapman Valve Mfg. Co., by Edward F. Hughes; Coffin Valve Co., by H. L. Weston; Hersey Mfg. Co., by Albert S. Glover, James A. Tilden and Walter A. Hersey; Wm. V. Briggs, by William F. Woodman; Henry F. Jenks; Lead Lined Iron Pipe Co., by Thomas E. Dwyer; Ludlow Valve Mfg. Co., by H. F. Gould; H. Mueller Mfg. Co., by W. L. Dickel; National Meter Co., by Charles H. Baldwin and J. G. Lufkin; Neptune Meter Co., by W. H. Van Winkle and H. H. Kinsey; Perrin, Seamans & Co., by J. C. Campbell; Rensselaer Mfg. Co., by Fred S. Bates; Stilwell-Bierce and Smith-Vaile Co., by F. H. Hayes; Sumner & Goodwin Co., by H. A. Gorham; Thomson Meter Co., by S. D. Higley; Union Water Meter Co., by F. L. Northrop and A. S. Otis; Henry R. Worthington, by Samuel Harrison. — 25.

GUESTS.

L. C. McDermott, Superintendent Water Works, East Orange, N. J.; C. E. Bliss, C. F. Holmes, Attleboro, Mass.; Henry E. Perry, Superintendent Water Works, Dover, N. H.; H. L. Dunn, Hopedale, Mass.; W. B. Webber Brookline, Mass.; Charles A. Dean and W. H. Butler, Water Commissioners, Wakefield, Mass.; F. A. Allen, Cambridge, Mass.; J. E. Bunting, Boston; Walter Phillips, Weymouth, Mass.; Hon. Leonard B. Chandler, Mayor-elect of Somerville, Mass.; H. C. Hunter, Marlboro, Mass.; George Goodhue, Concord, N. H.; W. E. Lord, A. H. Plouff, Ipswich, Mass.; S. E. Kieffer, Cambridge, Mass., and George Z. Taft, Uxbridge, Mass. — 18.

(Names counted twice, — 3.)

The Secretary read the following names of applicants for membership, the applications having been approved by the Executive Committee:

For Resident Member.— Gorham Dana, Boston, Mass., Manager Underwriters' Bureau of New England; Henry E. Perry, Dover, N. H., Superintendent Dover Water Works.

For Non-Resident Member. —L. C. McDermott, East Orange, N. J., Superintendent East Orange Water Department; George A. Taber, Brooklyn, N. Y., Assistant to Chief Engineer, Department of Water Supply, New York City; Worthington Scranton, Assistant to President, Scranton Gas and Water Company.

On motion of Mr. Coggeshall the Secretary was directed to cast one ballot in favor of the applicants, which he did, and they were thereupon declared elected members of the Association.

MR. CHARLES W. SHERMAN. In view of the fact that so many of our members had such a pleasant trip this morning through the East Boston tunnel, I think a vote of thanks to the chief engineer and to the Boston Transit Commission will not be out of place, and I therefore move the adoption of the following vote:

Voted, That the thanks of the Association be given to Mr. Howard A. Carson, chief engineer, and through him to the Boston Transit Commission, for courtesies extended to us at our visit to the East Boston tunnel this forenoon.

Adopted.

MR. HENRY F. JENKS. I wish to say a few words, Mr. President, and if what I am about to say does not seem to be proper I had rather not be called to order until after I get through. Many of us who are now here remember our trip to Montreal last September, and we know that it must have required a great deal of

hard work and the exercise of good judgment to have worked out the details of the trip as nicely as it was done. Everything passed off very pleasantly, and for the Associates I can say that we had the best rooms for our exhibition that we have ever had; and I think we all agree that the trip was one of the best the Association has ever made. I therefore move a vote of thanks to our efficient committee, Mr. Merrill, Mr. Holden, and Mr. Kent, and to such others as assisted in making the occasion so pleasant for us.

THE PRESIDENT. It is not in order to pass a vote of thanks to members of the Association for anything they do for us. So, while they are certainly entitled to our thanks, and we can think so as much as we please, yet it will not be in order to put your motion, Mr. Jenks.

MR. JENKS. That is satisfactory to me.

The President then introduced Hon. L. B. Chandler, the newly elected mayor of Somerville, who made a brief response.

The first paper of the afternoon was by Mr. W. H. Richards, Engineer and Superintendent of Water Works, New London, Conn., entitled, "Notes on the Building of a Storage Reservoir."

Mr. L. M. Hastings, C. E., Cambridge, Mass., then presented a paper on "Rainfall and Run-Off from Catchment Areas," which was discussed by Professor Porter and Mr. R. A. Hale.

MR. W. R. GROCE. Some three years ago, Mr. President, I had a bill put into the Legislature providing that the matter of the collection of water rates be put on the same basis as the collection of taxes, that is, that the real estate be holden for the water rates, but the committee to which it was referred reported that it was not desirable to pass it. Now, I should like to have this Association take that matter up, and I move that a committee be appointed to consider the advisability of asking the Legislature to pass such a bill, so that we can collect the water rates from the owner of the real estate, just the same as the tax collector can collect the taxes.

MR. DEXTER BRACKETT. I should like to ask if it is the intention that this committee shall have authority to represent the Association before the Legislature.

THE PRESIDENT. I so understand it.

MR. C. F. KNOWLTON. I don't believe the Association wants to send a committee to the Legislature to tell the Legislature

that the Association desires certain legislation. If a committee is to be appointed I think the committee should report back to the Association and then we can discuss the matter here.

MR. GROCE. I will move, Mr. President, that the matter be referred to a committee of three for its consideration, the committee to report at the next meeting.

The motion was adopted and the President announced he would take time to appoint the committee.

Adjourned.

ANNUAL MEETING.

HOTEL BRUNSWICK,
BOSTON, January 13, 1904.

President Charles K. Walker in the chair.

The following members and guests were present:

MEMBERS.

S. A. Agnew, C. F. Allen, C. H. Baldwin, L. M. Bancroft, J. E. Beals, F. D. Berry, J. M. Birmingham, J. W. Blackmer, George Bowers, Dexter Brackett, E. C. Brooks, G. A. P. Bucknam, George Cassell, G. F. Chace, J. C. Chase, S. K. Clapp, F. C. Coffin, R. C. P. Coggeshall, M. F. Collins, W. R. Conard, F. W. Dean, H. P. Eddy, J. N. Ferguson, J. H. Flynn, F. F. Forbes, F. L. Fuller, Albert S. Glover, W. J. Goldthwait, F. E. Hall, J. O. Hall, J. C. Hammond, Jr., J. D. Hardy, G. H. Hart, L. M. Hastings, T. G. Hazard, Jr., D. A. Heffernan, H. G. Holden, E. W. Kent, Willard Kent, E. S. Larned, J. W. Locke, H. V. Macksey, N. A. McMillen, A. E. Martin, W. E. Maybury, F. E. Merrill, Leonard Metcalf, H. A. Miller, F. L. Northrop, W. W. Patch, H. E. Royce, G. A. Sanborn, C. M. Saville, E. M. Shedd, C. W. Sherman, J. Waldo Smith, G. H. Snell, Henry Souther, G. A. Stacy, J. T. Stevens, L. A. Taylor, R. J. Thomas, H. L. Thomas, William H. Thomas, J. L. Tighe, D. N. Tower, W. H. Vaughn, C. K. Walker, R. S. Weston, J. C. Whitney, G. E. Wilde, F. I. Winslow, H. B. Wood. — 73.

HONORARY MEMBER.

F. W. Shepperd. — 1.

ASSOCIATES.

Builders Iron Foundry, by F. N. Connet; Coffin Valve Co., by H. L. Weston; Hersey Mfg. Co., by Albert S. Glover, J. A. Tilden and W. A. Hersey; Henry F. Jenks; Lead Lined Iron Pipe Co., by Thomas E. Dwyer; Ludlow Valve Mfg. Co., by H. F. Gould; H. Mueller Mfg. Co., by W. L. Dickel; National Meter Co., by C. H. Baldwin and J. G. Lufkin; Neptune Meter Co., by William H. Van Winkle; Norwood Engineering Co., by H. W. Hosford; Perrin, Seamans & Co., by James C. Campbell; Rensselaer Mfg. Co., by Fred

S. Bates; Sweet & Doyle, by H. L. DeWolfe; Thomson Meter Co., by S. D. Higley; Union Water Meter Co., by F. L. Northrop, F. E. Hall and L. P. Anderson. — 20.

GUESTS.

A. E. Pickup, Water Registrar, and Hugh McLean, Water Commissioner, of Holyoke, Mass.; W. H. Patterson, Superintendent Water Works, Providence, R. I.; Edwin P. Longley, Marlboro, Mass.; F. L. Weaver, Chairman Water Board, Lowell, Mass.; Hon. Cornelius F. Lynch, Lawrence, Mass.; R. A. Thayer, Woonsocket, R. I.; Horace Hart, Boston; and John W. Kernan, Wakefield, Mass. — 9.

(Names counted twice. — 4.)

The following were elected to membership:

Resident Members. — A. E. Pickup, Water Registrar, Holyoke Water Works; Hugh McLean, Secretary Water Commissioners, Holyoke, Mass.

Non-Resident Member. — Edward S. Cole, in charge of Water Waste Investigation of New York City.

Associates. — Fred A. Houdlette, Boston, manufacturer and dealer in water works and sewage steel and iron supplies; Hart Packing Co., Boston, manufacturers of steam and water packings.

The President appointed Messrs. J. L. Tighe, of Holyoke, and Harry L. Thomas, of Hingham, tellers to canvass the ballots for officers for the ensuing year.

Mayor Lynch of Lawrence was then introduced, and he spoke as follows:

Mr. President and Gentlemen of the Water Works Association, — I am rather surprised to be called on for any remarks. Being newly elected mayor, I am hardly familiar with the workings of any of the departments as yet, but it gives me great pleasure to meet a body of men organized for the purposes for which you are associated. I think it is a benefit to the municipalities, as well as to the superintendents and the water boards of the different cities and towns, that you should have such an organization and should hold these meetings where you can interchange ideas in the line of your work. I think it makes men broader, and the broader they are in their ideas, the better ideas they get through association with others, the better it is for the cities that they represent.

I came here as the guest of the superintendent of our water

works, and I am very glad I came. I want to say, without flattery, that we are favored in Lawrence by having as the superintendent of our water department a man in whom I believe all the citizens of Lawrence have perfect confidence, a man whose character for honesty and ability to perform the duties of the office is without question. [Applause.]

THE PRESIDENT'S ANNUAL ADDRESS.

President Walker addressed the Association as follows:

To the Members of the New England Water Works Association:

Gentlemen, — Another year has come and gone, and with it many pleasant days and remembrances that I have experienced with this organization.

Merrill, Kent, and Sherman told me at the time I was elected that they would assist and do whatever they could to make it easy for me in my present office. They have more than fulfilled their verbal contract, and I wish to thank these gentlemen to-day for their assistance and coöperation.

Of the twenty-one past presidents, eight have died, and the rest still belong to this Association. You will notice from the list that we have lost by death during the year three active members, namely, Joel Foster, of Montpelier, Vt.; Charles F. Parks, 14 Beacon Street, Boston; and George A. Ellis, of Springfield, Mass.; also two honorary members, namely, Alphonse Fteley, of New York City, and James M. Gale, of Glasgow, Scotland.

As you will learn from the Secretary's report, our total membership to-day is less by one than it was a year ago. We now have 586 members of all classes on our rolls.

When this Society was formed in April, 1882, it was for the purpose of meeting together to talk over the experiences which we had in our own cities and by getting the experiences of others, to make these meetings a mutual benefit to all of us in the Water Works Department. I shall never forget the first meeting that we had. The acquaintances that I made then have made my life happier, and what I have since learned has been a great benefit to me.

This year we have settled one question, — that the water furnished for fire sprinklers should be paid for; in what way has not been settled. We do not care how we get it, but we should be paid for the water furnished.

We have got the specifications for cast-iron pipe, and I, for one, will stick to them, for they suit me the best.

We have had interesting meetings and two excursions. The one in June was very pleasant and the sail up the Charles River, which has since been a noted place for canoeing, was a very pleasant trip for me. The watch factory was quite a curiosity, and I shall always feel indebted to my friend Winslow for having this trip made during my administration. The trip to Montreal was the best of the season, — and cost the most money, — but no one regrets it on that account. The whole thing was a success, the weather was perfect, and the ride through the mountains was immense. We must give Merrill and Holden credit for this excursion to a foreign land, which some of us never expected to see. Thanking you for the many favors received, I bespeak for my successor in the office of President, which I shall soon vacate, the same courtesy and kindness which you have all shown to me. [Applause.]

REPORT OF THE SECRETARY.

Secretary Kent submitted the following annual report, which, on motion of Mr. Cassell, was accepted and ordered to be placed on file:

Mr. President and Gentlemen of the New England Water Works Association, — I have the honor to submit the following report of membership, receipts, and disbursements of the New England Water Works Association for the year ending December 31, 1903.

Membership.

The total membership of the Association, January 1, 1903, was	587
The present membership (January 1, 1904) is	586

The membership is divided as follows:

MEMBERS.

Total active membership, January 1, 1903, was		522	
Withdrawals during past year:			
Resignations	22		
Dropped	26		
Died	3	51	
		471	
Initiations during past year:			
January	7		
February	5		
March	5		
June	7		
September	24		
November	3		
December	5	56	
Reinstated		1	528

HONORARY MEMBERS.

Number of honorary members, January 1, 1903, was		5	
Died during year		2	3

ASSOCIATES.

Total associate membership, January 1, 1903, was		60	
Withdrawals:			
Resignations	5		
Dropped	3	8	
		52	
Initiations during past year:			
September	3	3	55
Total membership, January 1, 1904, is			586

SUMMARY OF RECEIPTS AND DISBURSEMENTS OF THE NEW ENGLAND WATER WORKS ASSOCIATION FOR THE YEAR 1903.

RECEIPTS.

Dues	$2 540.50
Advertisements	1 539.75
Initiations	340.00
JOURNALS sold	219.08
Subscriptions	157.25
Sales of Pipe Specifications	116.90
Sundries	29.42
	$4 942.90

DISBURSEMENTS.

JOURNAL (including membership list)	$1 526.66
Stationery	425.61
Rent	400.00
Assistant Secretary	390.00
Editor	300.00
Advertising Agent	280.10
Incidental Expenses	240.38
Secretary	200.00
Reprints	167.75
Pipe Specifications	139.40
September Excursion	112.59
Stenographer	107.25
Badges	62.11
Stereopticon	58.00
Music	50.00
Exhibit	34.60
June Excursion	10.63
Total	$4 505.08

Amount of Receipts above Expenditures	$437.82
At the present time there is due the Association:	
For dues	$240.75
For advertisements	171.25
For sundries	4.80
Total	$416.80

The bill for the printing of the December issue of the JOURNAL is not yet received.

I know of no other outstanding bills against the Association.

Respectfully submitted,

WILLARD KENT, *Secretary.*

REPORT OF THE TREASURER.

The Treasurer, Lewis M. Bancroft, submitted the following report, which, on motion of Mr. Frank L. Fuller, was accepted and placed on file:

LEWIS M. BANCROFT,
In account with The New England

RECEIPTS.

1903.				
January 9.	Balance on hand			$2 541.73
August 1.	Dividend, People's Savings Bank			53.80
December 6.	Dividend, Mechanics Savings Bank			35.70
March 4.	Received of Willard Kent, Sec'y		$1 817.23	
April 15.	" " " "		616.79	
June 18.	" " " "		624.48	
July 14.	" " " "		111.50	
September 28.	" " " "		376.90	
December 4.	" " " "		798.90	
1903.				
January 4.	" " " "		597.10	4 942.90
				$7 574.13

Examined and found correct.

E. J. CHADBOURNE,
Finance Committee.

TREASURER,
Water Works Association.

EXPENDITURES.

Bills paid, as per itemized statement following	$4 505.08

BALANCE ON HAND.

Deposit People's Savings Bank, Worcester	$1 398.98	
Deposit Mechanics Savings Bank, Reading	1 047.12	
Deposit First National Bank, Reading	622.95	
Balance on hand		3 069.05
		$7 574.13

LEWIS M. BANCROFT,
Treasurer.

DETAILED STATEMENT OF BILLS PAID.

1903.			
February	2.	Hobbs & Warren Co., paper	$2.49
		Hub Engraving Co., plates	6.72
		Thomas P. Taylor, stereopticon, January meeting	10.00
	5.	Samuel Usher, printing	49.50
		Hub Engraving Co., plates	29.81
	11.	J. M. Ham, salary and expenses Assistant Secretary to February 1	34.35
		Hooper, Lewis & Co., letter book and cards	5.50
March	4.	D. Gillies' Sons, envelopes and letter paper	93.44
		W. N. Hughes, bills and envelopes	15.25
		Hub Engraving Co., plates	17.20
		Edgar D. Sewall, drawings	16.25
		Amarina & Peters, music, January and February meetings	20.00
		Thomas P. Taylor, stereopticon, February meeting	10.00
		Helen A. Thomas, four days' services	6.65
	5.	D. Gillies' Sons, printing	5.39
		J. M. Ham, salary and expenses to March 1	57.00
		W. N. Hughes, large envelopes	47.75
		Boston Society of Civil Engineers, rent to February 26	100.00
	16.	Hub Engraving Co., plates	13.65
		Samuel Usher, printing	197.50
		Amarina & Peters, music, March meeting	10.00
	24.	W. N. Hughes, bills	2.80
		Charles W. Sherman, salary to April 1 and expenses	82.30
	30.	Bacon & Burpee, reporting January, February, and March meetings	30.00
April	4.	Robert J. Thomas, advertising agent to April 1	80.55
		J. M. Ham, salary and expenses to April 1	33.96
	6.	D. Gillies' Sons, blank book	7.85
		Samuel Usher, March JOURNAL	310.95
		Hub Engraving Co., plates	16.19
	10.	Willard Kent, salary and expenses to March 31,	90.70
		Hooper, Lewis & Co., cards, etc.	1.50
	22.	Samuel Usher, reprints	25.75
		Amount carried forward	$1,431.00

	Amount brought forward	$1 431.00
May 1.	William H. Lawrence, lantern slides	5.50
	American Society of Civil Engineers, binding transactions	6.40
27.	J. M. Ham, salary to May 1	35.00
	Hub Engraving Co., plates	5.40
June 13.	Hub Engraving Co., plates	48.01
	J. M. Ham, salary for May	35.00
19.	D. Gillies' Sons, printing circulars	4.85
	Library Bureau, pamphlet cases	10.88
29.	Charles W. Sherman, salary and expenses to July 1	81.65
	George E. Winslow, tickets, etc., June outing	5.81
	Rand Avery Supply Co., tickets	1.50
	Frank E. Merrill, expense June outing	3.32
	Willard Kent, salary and expenses to July 1	61.00
July 6.	Samuel Usher, June JOURNAL	345.35
9.	Samuel Usher, reprints	47.50
15.	Robert J. Thomas, advertising agent to July 1,	72.05
	J. M. Ham, salary to July 1	35.00
27.	Boston Society of Civil Engineers, rent to May 31	100.00
August 26.	Hub Engraving Co., plates	6.16
	Samuel Usher, printing	36.50
	Willard Kent, expenses of committee, September convention	75.00
	J. M. Ham, salary to August 1	35.00
September 5.	J. M. Ham, salary to September 1, express, postage, etc	60.42
22.	Bishop Engraving & Printing Co., printing	14.25
	Hub Engraving Co., plates	21.18
	Library Bureau, cards and tray	3.41
	Whitehead & Hoag Co., badges	24.11
	W. F. Almy, badges	38.00
	W. N. Hughes, envelopes and printing	26.00
	Henry F. Jenks, expenses, committee on exhibits, Montreal convention	34.60
29.	Thomas P. Taylor, stereopticon, Montreal convention	38.00
	Charles W. Sherman, salary, expenses, and postage to October 1	84.25
	Samuel Usher, reprints	34.00
	The Somerville Journal Co., printing	3.50
	Frank E. Merrill, telephone, telegraph, and express	5.59
	Amount carried forward	$2 875.19

	Amount brought forward	$2 875.19
September 29.	Car fare T. P. Taylor, Montreal and return	16.00
October 2.	D. Gillies' Sons, printing notices	72.00
	Willard Kent, salary to October 1 and expenses	73.00
8.	J. M. Ham, salary to October 1	35.00
13.	Robert J. Thomas, advertising agent, to October 1	64.25
21.	Hub Engraving Co., plates	33.51
	Boston Society of Civil Engineers, rent to August 31	100.00
29.	Hub Engraving Co., plates	14.78
	George J. Sinnett, repairing furniture	2.50
	Buildings Cleaning & Renovating Co., cleaning	4.55
November 13.	J. M. Ham, salary to November 1	35.00
	D. Gillies' Sons, envelopes and printing	35.20
21.	J. Dennison, plates	43.33
	Charles W. Sherman, paid for drawings, duty on cuts, etc.	20.04
December 4.	Samuel Usher, September JOURNAL	360.24
	W. N. Hughes, binding books	5.00
7.	Hub Engraving Co., plates	24.83
	Samuel Usher, reprints	29.75
	J. M. Ham, salary to December 1	35.00
	Bacon & Burpee, stenographers, September and November meetings	69.25
14.	Hub Engraving Co., plates	4.24
	Library Bureau, card index of JOURNAL	67.11
	Amarina & Peters, music, November and December meetings	20.00
26.	Robert J. Thomas, advertising agent to January 1, 1904	63.25
	Charles W. Sherman, salary and expenses to January 1, 1904	75.75
	J. M. Ham, salary to January 1, 1904	35.00
29.	Bacon & Burpee, report of December meeting,	8.00
	Samuel Usher, printing	5.50
	Willard Kent, salary and expenses to January 1, 1904	91.00
1904.		
January 2.	D. Gillies' Sons	40.70
7.	Boston Society of Civil Engineers, rent to December 1, 1903	100.00
12.	J. M. Ham, expenses to January 1, 1904	46.11
	Total bills paid	$4 505.08

REPORT OF THE EDITOR.

Mr. Charles W. Sherman, the editor, submitted the following report, which, on motion of Mr. Stacy, was accepted and placed on file:

BOSTON, January 13, 1904.

To the New England Water Works Association, — The following is my report as Editor of the JOURNAL for the year 1903:

The December issue of the JOURNAL, which has just appeared after many delays, contains twenty-five and one-quarter pages of paid advertisements, of an annual value of $1 750. A year ago we had twenty-seven and one-third pages of paid advertisements of a value of $1 929. This shows a loss of $179 worth of advertisements during the year. Our advertising agent has been assiduous as ever in his attempts to secure and retain advertising, and the only conclusion to be drawn from the falling off of patronage is that the members do not pay sufficient attention to the advertising to make the advertising pages of sufficient value to those advertisers who have withdrawn.

As was the case a year ago, the December issue has been delayed to such a time that it has not been possible to send out bills for the advertising in that issue and get any returns from them. The receipts for 1904 will consequently show a considerable sum which properly belongs to the JOURNAL for 1903.

The accompanying tables show in detail the amount of material in the JOURNAL, the receipts and expenditures, and a comparison with the three preceding volumes.

TABLE No. 1.

STATEMENT OF MATERIAL IN VOLUME XVII, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, 1903.

Number.	Date of Issue.	Number of Pages of								
		Papers.	Proceedings.	Total Text.	Index, etc.	Advertisements.	Covers and Contents.	Inset Plates.	Total.	Cuts.
1	March	96	30	126	—	34	4	2	166	19
2	June	104	4	108	—	31	4	12	155	11
3	September	63	7	70	—	27	4	14	115	4
4	December	113	13	126	10	27	4	16	183	8
	Total	376	54	430	10	119	16	44	619	42

TABLE No. 2.

RECEIPTS AND EXPENDITURES ON ACCOUNT OF VOLUME XVII, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, 1903.

RECEIPTS.		EXPENDITURES.	
From advertisements	$1 539.75	For printing JOURNAL	$1 433.09*
From sale of JOURNALS	219.08	For preparing illustrations	314.76
From sale of reprints	19.35	For Editor's salary	300.00
From subscriptions	157.25	For Editor's incidentals	30.49
	$1 935.43	For Advertising Agent's commissions	280.10
		For reporting	107.25
		For reprints and advance copies	167.75
		For statistics forms	5.50
Net cost of JOURNAL	770.62	For index to JOURNAL	67.11
	$2 706.05	Gross cost of JOURNAL.	$2 706.05*

* This includes bill for December JOURNAL, which has just been received but not paid, and consequently does not appear in the Secretary's and Treasurer's reports.

TABLE No. 3.

COMPARISON BETWEEN VOLUMES XIV, XV (4 NUMBERS), XVI, AND XVII, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

	Vol. xiv.	*4 numbers of Vol. xv.*	*Vol. xvi.*	*Vol. xvii.*
Edition (copies)	1 100	1 200	1 200	1 200
Average membership	583	586	571	587
Pages of text	345	363	403	430
Pages of text per 1 000 members	600	618	707	733
Total pages, all kinds	485	536	584	619
Total pages per 1 000 members	832	913	1 020	1 051
GROSS COST:				
Total	$1 954.15	$2 194.26	$2 439.99	$2 706.05
Per page	4.03	4.10	4.18	4.38
Per member	3.35	3.75	4.27	4.61
Per member per 1 000 pages	6.91	6.99	7.32	7.46
Per member per 1 000 pp. text	9.71	10.31	10.60	10.72
NET COST:				
Total	$347.55	$332.90	$622.89	$770.62
Per page	.72	.62	1.07	1.25
Per member	.60	.57	1.09	1.31
Per member per 1 000 pages	1.23	1.06	1.87	2.12
Per member per 1 000 pp. text	1.73	1.57	2.71	3.05

Without crediting the JOURNAL with any part of the dues paid by members, it will be observed that the expenses incurred on account of the JOURNAL amount to $770.62 more than the receipts. This is a larger net cost than we have had for some years, if ever before. It is largely accounted for, however, by the extra work undertaken; first in preparing a complete card index to the JOURNAL from the beginning, which has now been completed and installed at headquarters, and, second, in working up tables and making cuts to accompany the "Standard Specifications for Cast Iron Pipes and Special Castings."

Three thousand copies of the Standard Specifications have been printed in a separate pamphlet, most of which have been sold. The cost of printing and sending out specifications has been $139.40, and the receipts from sales $116.90, leaving a net cost to the Association of $22.50. This, however, does not include any of the expenses of preparing tables, illustrations, etc., all of which have been charged to the JOURNAL.

The usual fifty reprints of papers have been furnished to their authors without charge. The net cost to the Association of these reprints, including also advance copies of one or two papers, has been $5.94 for each paper reprinted.

The total cost of illustrations for this volume, including payments for drafting, making cuts, and printing inset plates, has been $508.01, or 18.75 per cent. of the gross cost of the JOURNAL.

The present circulation of the JOURNAL is:

Members (all grades)	586
Subscribers	52
Exchanges	18

The custom of sending out three hundred sample copies of each issue has been continued through the year.

The December issue having appeared so recently, the reprints from it have not yet been delivered and consequently the bill for these reprints has not been received. With this exception, I know of no outstanding bills against the Association on account of the JOURNAL.

Respectfully submitted,

CHARLES W. SHERMAN, *Editor.*

Mr. George A. Stacy read a paper by W. C. Hawley, General Superintendent Pennsylvania Water Co., Wilkinsburg, Pa., entitled, "Some Notes on Cost of Waterproofing Concrete Lining of Reservoirs." The subject was discussed by J. Waldo Smith, Frank L. Fuller, Edward S. Larned, and Robert J. Thomas.

ELECTION OF OFFICERS.

The tellers appointed to canvass ballots for officers for the ensuing year reported as follows:

Total number of ballots	219
For President.	
EDWIN C. BROOKS, Cambridge, Mass.	208
C. K. WALKER	3
For Vice-Presidents.	
V. C. HASTINGS, Concord, N. H.	207
GEORGE P. WESCOTT, Portland, Me.	207
JOSEPH E. BEALS, Middleboro, Mass.	208
E. W. KENT, Woonsocket, R. I.	208
GEORGE E. CROWELL, Brattleboro, Vt.	207
J. C. HAMMOND, Jr., Rockville, Conn.	208
For Secretary.	
WILLARD KENT, Narragansett Pier, R. I.	211
For Treasurer.	
LEWIS M. BANCROFT, Reading, Mass.	209
For Editor.	
CHARLES W. SHERMAN, Boston, Mass.	208
ALLEN HAZEN	1
For Advertising Agent.	
ROBERT J. THOMAS, Lowell, Mass.	209
FRED BATES *	1
For Additional Members of Executive Committee.	
FRANK E. MERRILL, Somerville, Mass.	207
GEORGE A. STACY, Marlboro, Mass.	207
H. G. HOLDEN, Nashua, N. H.	207
For Finance Committee.	
E. J. CHADBOURNE, Wakefield, Mass.	207
R. C. P. COGGESHALL, New Bedford, Mass.	210
W. W. ROBERTSON, Fall River, Mass.	207
D. W. FRENCH	1

* Ineligible.

President Walker in calling the newly elected President to the chair spoke as follows: I now present to you your new President, Mr. Brooks, of Cambridge. He holds the place once filled by Hiram Nevons, who was our fourth President, I think, and the Association then had two hundred and seventy-three members. We all used to like him very much, and I hope we will like his successor as well. Mr. Brooks is probably the best mechanical engineer who has ever been President of this Association. I hope he will have as nice a time being President as I have had, and I will now step down and out. [Applause.]

Mr. Brooks then took the chair and said: Gentlemen, I sincerely thank you for the honor you have conferred upon me, and hope that at the end of the year you will not have had cause to regret it.

William Lyman Underwood, Lecturer, Massachusetts Institute of Technology, Boston, then spoke on " Mosquitoes, with Suggestions for their Extermination." His remarks were illustrated by the stereopticon with photographs taken from life. Questions were asked and remarks made by Freeman C. Coffin, Frank L. Fuller, Robert J. Thomas, Harrison P. Eddy, S. A. Agnew, and F. W. Dean. On motion of Charles W. Sherman, a vote of thanks was tendered to Mr. Underwood for his very interesting address.

Freeman C. Coffin, Civil and Hydraulic Engineer, Boston, Mass., read a paper on " Meter Rates," and at its conclusion moved the adoption of the following vote:

That a committee of this Association be appointed to consider the question of meter rates for water service, collect and digest information, and submit to the Association a schedule or schedules designed to meet various conditions of a metered service, or a basis upon which such schedules can be arranged; that this committee consist of five members; that the committee be authorized to expend a sum not exceeding fifty dollars in printing, postage, and other necessary expenses involved in the collection of data.

Messrs. Frank L. Fuller, F. E. Merrill, and Charles W. Sherman spoke in favor of the motion, and it was adopted. The Chair announced that he would appoint the committee later. Subse-

quently Messrs. Freeman C. Coffin, C. M. Saville, G. P. Wescott, H. V. Macksey, and F. E. Merrill were appointed members of the committee.

PRESIDENT BROOKS. I want to say a word in regard to the coming year. I wish we might have more little practical points in water-works management brought up and discussed at the meetings. It seems to me that I hardly ever meet a superintendent and talk with him but what I find he has some little kink that is of use. Perhaps he does not think it of importance enough to communicate to others, but really it amounts to quite a little oftentimes; and I think we all might gain something from a freer interchange of ideas here.

MR. F. W. DEAN. I should like to ask how the subjects for the papers are determined in this Association, — whether they are originated by the Secretary, or whether he gets suggestions from other people to any great extent.

THE PRESIDENT. Mr. Secretary, you will please answer.

SECRETARY KENT. The Secretary is always very glad to get suggestions from other people, but as matter of fact it is usually a case of hustle with him.

MR. DEAN. When the President spoke of the matter of relating experiences it occurred to me that perhaps it might be interesting to state how the New England Railroad Club proceeds to have papers brought forward for discussion. I am a member of that club and have been a member of the committee of which I shall speak. The club has monthly meetings for eight months in the year, the second Tuesday of each month, and there is a sub-committee of eight or ten members, which committee gets together as many times as may be necessary during the summer and selects a list of subjects for the following year. After that is once done the series of meetings goes along very easily. Of course there is considerable correspondence in regard to it, and the committee often gets people from out of town, as well as members of the club, to present papers on various subjects. Then theoretically we have a list of subjects for discussion aside from the papers, the idea being to have subjects for short discussions, so as to fill in any gaps if the regular papers are not long enough to take up the usual time of the meeting. Almost always, how-

ever, the papers are long enough, and so these short discussions seldom take place. It occurred to me if the Secretary is at all embarrassed in getting papers, it might be well for the Association to have a sub-committee for that purpose.

THE SECRETARY. I think that is a very good suggestion, Mr. President.

MR. CHARLES W. SHERMAN. I move that the President be authorized to appoint such a committee at his discretion. Adopted.

Adjourned.

February Meeting.

Hotel Brunswick,
Boston, Mass., February 10, 1904.

President Edwin C. Brooks in the chair.

The following members and guests were present:

Members.

S. A. Agnew, C. H. Baldwin, L. M. Bancroft, William T. Barnes, J. E. Beals, George Bowers, E. C. Brooks, Fred. Brooks, George Cassell, G. F. Chace, J. C. Chase, F. C. Coffin, R. C. P. Coggeshall, M. F. Collins, F. H. Crandall, Gorham Dana, C. H. Eglee, F. F. Forbes, A. D. Fuller, F. L. Fuller, A. S. Glover, J. W. Goodell, X. H. Goodnough, F. W. Gow, R. A. Hale, J. O. Hall, V. C. Hastings, H. G. Holden, H. R. Johnson, E. W. Kent, Willard Kent, G. A. King, E. S. Larned, J. W. Locke, T. H. McKenzie, S. H. McKenzie, H. V. Macksey, W. E. Maybury, F. E. Merrill, T. L. Northrop, J. H. Perkins, W. W. Robertson, C. W. Sherman, G. H. Snell, G. A. Stacy, J. T. Stevens, R. J. Thomas, J. L. Tighe, W. H. Vaughn, C. K. Walker, F. I. Winslow, G. E. Winslow. — 52.

Associates.

Ashton Valve Co., by C. W. Houghton; Harold L. Bond & Co., by Harold L. Bond; Builders Iron Foundry, by F. N. Connet; Chapman Valve Mfg. Co., by Edward F. Hughes; Coffin Valve Co., by H. L. Weston; Garlock Packing Co., by Edward N. Corning; Hersey Mfg. Co., by Albert S. Glover, J. A. Tilden, and Walter A. Hersey; Fred A. Houdlette & Son, by Fred A. Houdlette; Lead Lined Iron Pipe Co., by T. E. Dwyer; H. Mueller Mfg. Co., by W. L. Dickel; National Lead Co., by G. L. Whittemore; National Meter Co., by C. H. Baldwin and J. G. Lufkin; Neptune Meter Co., by W. H. Van Winkle and H. H. Kinsey; Rensselaer Mfg. Co., by Fred S. Bates; A. W. Chesterton & Co., by William M. Rea; Central Foundry Co., by Mark Dean; Sumner & Goodwin Co., by H. A. Gorham; Sweet & Doyle, by H. L. DeWolfe; Thomson Meter Co., by S. D. Higley; Union Water Meter Co., by F. L. Northrop. — 24.

Guests.

John Mayo, Superintendent Water Works, Bridgewater, Mass.; Frank L. Weaver, A. J. Dowd, Water Commissioners, Lowell, Mass.; T. V. Sullivan, Water Department, Boston; J. H. Caldwell, Deputy Water Commissioner, Boston; and H. J. Jernegan, General Freight Agent, B. & P. S. S. Co. — 6.

Names counted twice. — 3.

The Secretary presented the names of the following applicants for membership, all of whom were properly endorsed and approved by the Executive Committee:

For Resident Member. — Virgil R. Connor, Fairfield, Me., Trustee Kennebec Water District; S. A. Nye, Fairfield, Me., Trustee Kennebec Water District; Ira E. Getchell, Waterville, Me., Trustee Kennebec Water District; Dr. F. C. Thayer, Waterville, Me., Trustee Kennebec Water District; John Mayo, Superintendent Bridgewater Water Co., Bridgewater, Mass.; Frank H. Carter, Cliftondale, Mass., Civil Engineer, Assistant Engineer with Leonard Metcalf, of Boston; Louis D. Thorpe, West Medford, Mass., Civil Engineer, Principal Assistant to Freeman C. Coffin.

For Non-Resident Member. — Wm. M. Marple, Scranton, Pa., Chief Engineer of the Scranton Gas and Water Co., and other companies.

For Associate. — The Wm. Tod Co., Youngstown, Ohio, builders of high duty pumping engines.

On motion of Mr. Fuller the Secretary was empowered to cast one vote for the applicants whose names had been read, and he having done so they were declared elected.

Place of Annual Convention.

The President. I wish to announce that the invitation from Holyoke has been accepted, and the fall convention will be held there some time in September.

Proposed Legislation affecting Purity of Water Supplies.

I should like to say to the members from Massachusetts that there is a bill before the Legislature, Senate No. 87, that very seriously modifies and affects the rights of water-takers in the great ponds and streams of the state. In order that you may know more fully what some of the features of this bill are, I will ask Mr. Goodnough to speak to you.

Mr. X. H. Goodnough. *Mr. President and Gentlemen,* — This is Senate Bill No. 87 accompanying a petition for an amendment to the law relative to the pollution of water supplies of cities and towns, and it is now before the Public Health and Water Supply committees jointly. I will not read it all, but it is a modification of the present legislation authorizing the State Board of Health to make rules and regulations for the protection of water supplies. The bill is the most pernicious piece of proposed legislation affect-

ing the purity of water supplies that has appeared for some time. Its chief objectionable features are, first, that it provides that any one aggrieved by the enforcement of the rules and regulations of the Board of Health may recover damages; in other words, it authorizes people living about great ponds to recover damages for the exercise of police power — a new thing in law, I believe. The other chief objectionable feature is found in Section 2: "The State Board of Health shall not make rules or regulations or orders prohibiting or restricting boating, fishing, or ice cutting on any great pond." The effect of that, of course, would be that the surfaces of great ponds may be used as pleasure resorts without any restriction whatever. People might launch boats, and as has happened in one case, might launch house boats on a pond and anchor them over an intake, if they saw fit, and no authority could remove them. The water supplies of this state are used by something like 92 per cent. of the population, five sixths of whom are dependent upon supplies taken from surface sources, very largely from great ponds, and it is essential that the purity of those waters should be protected.

In recent years there has been a very rapid growth in the use of ponds and reservoirs, especially great ponds, as summer resorts, and there has been a very rapid growth in the number of cottages about those ponds and in picnic and other pleasure resorts on their shores, which the rules of the Board of Health have been invoked to prevent. This proposed legislation is really for the benefit of the very few to the injury of the very great majority. The legislation to protect our water supplies has grown up, I may say, since 1878, when the first act was passed to prohibit their pollution. That is the act which is sometimes known as the twenty-mile law, and it provided that no sewage should be discharged into a stream or pond within twenty miles of the point from which water is taken for a public supply. In 1890 the first act giving the State Board of Health authority to make rules and regulations was passed. That was revised and the powers of the Board greatly enlarged by the act of 1897, which was changed somewhat when the Revised Laws were established in 1902.

One object of this proposed law is to provide, or is said to be to provide, for an appeal to a jury for the revision of the rules of the Board. Of course we all know the danger of submitting

such matters to a jury, especially the protection of public water supplies. It is argued that in some cases the waters could be protected by filtration. That is a very good method of protecting a public water supply, but it is needless to say that filtration is not the only protection, and no one wants to drink water that has been polluted by sewage, even if it has subsequently been purified by filtration. It is essential to keep the sources pure in the beginning. It is hoped that those who are interested in this legislation, and nearly all the water-works men in the state should be, will take an active interest at least so far as to appear at the hearing when the matter comes up. The date of the hearing has not yet been assigned.

THE PRESIDENT. I will ask Mr. King, of Taunton, to favor us with a few remarks.

MR. GEORGE A. KING. *Mr. President and Gentlemen,* — I suppose this bill was aimed directly at Taunton, but it will affect every city or town which has had rules made for it by the State Board of Health, or any which may have them made in the future. It opens a great source of damage cases, and any party who lives on the watershed of a water supply will have an opportunity to bring a suit for damages, and the same body which has the power to amend or annul the rules, that is, the jury, will have the power to assess the damages; and as these damages will be assessed in the county where the land lies it will probably be hard to get a fair jury as between the individual and the municipality or the owner of the water supply. I think, as Mr. Goodnough has said, that this would be a most pernicious piece of legislation, and I would like to have the assistance of all the water-works people in the attempt to defeat the bill. If you will see the members of the House and Senate from your various sections, I think we can easily defeat it. Of course the cottagers have considerable money to spend on this matter and the cities and towns haven't much, so we must depend on our individual efforts.

THE PRESIDENT. Mr. Chace, will you say something?

MR. GEORGE F. CHACE. Mr. President, I think this is a very important matter. It seems to me it would be a good thing if there were some organized action on the part of this Association by the appointment of a committee to make an active opposition to the bill, and I would move that a committee be appointed by the Chair to attend the hearing.

THE PRESIDENT. I must say that I have had some doubts as to whether it was best for the Association to take action in this matter as an Association, and my idea in bringing up this discussion was that the Massachusetts superintendents might be informed as to what was pending, so that they could use their individual efforts with the members of the Legislature from their respective districts to defeat the proposed bill. Of course this is a New England organization and not merely a Massachusetts organization, and it is a question in my mind whether it would be policy for us to take action as an association in regard to this matter. I shall be happy to hear from any of the members on the subject, for I think it is one which is worthy of discussion.

MR. R. C. P. COGGESHALL. Perhaps some such action as advising the Massachusetts members when the hearing on this bill is to be held, might help to defeat the measure.

THE PRESIDENT. Can we hear from Ex-Mayor Hall on this matter?

MR. JOHN O. HALL. I do not know as I can add anything to what has been said, Mr. President, but I think it certainly is the duty of the Massachusetts members of the New England Water Works Association to interest themselves and be active in their opposition to this measure. It certainly is of vital importance that it should be defeated, and we should all use our best efforts to sustain the State Board of Health in their very successful measures to ensure the purity of the water supplied to our people. And while it seems to me no action could properly be taken before the Legislature by us as an organization, I trust that every individual member of the Association who lives in Massachusetts will give it his personal attention.

MR. M. F. COLLINS. It strikes me, Mr. President, that one of the duties of this organization, when a question of this kind comes up, is to act upon it as a body. If this proposed legislation is against the best interests of the water-takers of New England, then I think this Association ought to be used for the purpose of defeating it. I think it comes with good grace for this Association to take action as a body on such a question as this. It stands well in Massachusetts, and its opinion will have some weight. Then, after we have acted here, let every member of the Association work on the Representatives from his district

individually, backed up by the voice of this Association, which is organized for the very purpose of looking after the interests of the water-takers of New England. In order to bring the matter properly before the Association, I move that a committee be appointed to appear before the Legislative Committee and represent the New England Water Works Association.

MR. CHARLES K. WALKER. Before the motion is seconded I have a little to say. I think Mr. Coggeshall has the right of it. We in New Hampshire are not interested in the Massachusetts Legislature, and in what they do or in what they do not do. Now if you take a vote here of the Association you bring in representatives from every state in New England, and is that right? If you have some trouble here in your Massachusetts Legislature, why shouldn't the representatives of Massachusetts attend to it, and why isn't the best way to do as was done before — merely notify the Massachusetts members of the Association in regard to the matter? If we vote as an Association, I have got to vote, and I live in New Hampshire, and New Hampshire hasn't anything to do with Massachusetts water.

MR. J. O. HALL. It seems to me it will be very much better for the Association to act through the individual members rather than to take any special action as a body. I would like to say that I am president of the Massachusetts Auditors Association, and we have under consideration the question of what is called uniform accounting. A motion was made in that association that we send a committee to the Legislature this winter to represent us in the interest of a certain bill. Objection was made by some of the best auditors in the state, the most level-headed and thoughtful of the members, that there would attach to such action a certain political element which would be objectionable and would be of disadvantage to the association. And it seems to me that the same argument holds good in the consideration of the question now before us. This is an organization intended for the advancement of the scientific and mechanical and financial elements in water-works problems, and there is a certain element of a political nature which enters into this bill, and if we were to send a committee to the Legislature, with the authority of the Association back of it, it seems to me that it might be an element of weakness in the presentation of the case. I think that this

thing can be reached and fully presented and earnestly and effectively argued against if each member of the Association acts individually and to a certain extent independently. In that way any question of political action would be avoided and the same result would be accomplished.

MR. CHARLES W. SHERMAN. I am inclined to agree with Mr. Hall's views. I think, however, as Mr. Collins does, that the Association should concern itself with such a matter as this, certainly to the extent of discussing the matter as we have to-day, and that it would also be entirely in order for the Association to go a little further and authorize the expenditure of a small sum of money in printing a notice that this bill is coming up, and that the matter has been talked over at the meeting to-day, giving a brief statement of what the effect of the passage of the bill would be, and mailing the notices to each Massachusetts member of the Association, and also to every water-works superintendent in Massachusetts who is not a member of the Association, with the suggestion that if members agree with the opinions expressed here to-day they use their best endeavors with their Senators and Representatives to defeat the bill; and also if convenient that they attend the hearings. And as the other motion has not been seconded, if it is in order, I will make a motion that the Secretary be authorized to issue a brief circular describing this bill and suggesting that members interest themselves in it, and call the attention of their Representatives in the Legislature to the effect that the passage of the bill would have.

Mr. J. C. CHASE. I would like to present one point of view very briefly in this connection, and that is, Would the Association consider itself called upon to interfere in case such legislation as this was attempted in any other New England state except Massachusetts?

THE PRESIDENT. Is Mr. Collins' motion seconded? If not, is Mr. Sherman's motion seconded?

MR. L. M. BANCROFT. I second Mr. Sherman's motion.

MR. SHERMAN. Before the motion is put I would like to say, in answer to Mr. Chase's question as to whether similar action would be taken if such legislation were proposed in any other state than Massachusetts, that I think it would be entirely proper for the Association to interest itself to the same extent in regard

to legislation in any of the New England states. But I think it is especially proper in this case, inasmuch as the sanitary legislation for the protection of water supplies in Massachusetts is looked upon throughout the country, and almost throughout the world, as a model to be followed.

MR. GOODNOUGH. I should like to suggest as an amendment to Mr. Sherman's motion that notice be sent out by the Secretary giving the time assigned for the hearing.

MR. SHERMAN. I accept that amendment.

MR. COLLINS. And I would like to have Mr. Sherman added to the committee to act with the Secretary.

MR. J. E. BEALS. I would like to suggest also that a copy of the bill that is to be presented be sent out with the notices.

(Mr. Sherman's motion as amended was adopted.)

THE PRESIDENT. Now in regard to the composition of this committee, perhaps it might be well to have more than the Secretary and Editor on the committee; what is your pleasure in regard to that?

MR. WILLARD KENT. I move that Mr. Goodnough and Mr. King be added to the committee.

Adopted.

Mr. Goodnough asked to be excused from serving on the committee, on the ground that the matter was coming before the Board of Health in rather an official way. Mr. G. A. Stacy was suggested, and he was added to the committee.

The first paper of the afternoon consisted of extracts from "Report Relative to supplying the City of New York with Pure and Wholesome Water, November, 1833," compiled by James M. Betton, of New York City, and read by Charles W. Sherman.

The next paper was by J. H. Purdy, of Pittsburgh, Pa., entitled, "Fire Protection for Factories: How its Value shall be Determined and Who shall Pay for It." In the absence of Mr. Purdy, Mr. F. H. Crandall read the paper, and he also read a report of progress by the Committee on Private Fire Services. The reading of the paper and of the report was followed by an exhibition by Mr. Crandall of stereopticon views of the apparatus used in the experiments at Knoxville and Burlington. The discussion was participated in by Messrs. T. H. McKenzie, Gorham Dana, Robert J. Thomas, John C. Chase, E. W. Kent, Frederick N. Connet, and Leonard Metcalf.

The President then brought up the subject of the freezing of meters during the past winter, and experiences were related by Messrs: E. W. Kent, Horace G. Holden, Robert J. Thomas, George A. King, George F. Chace, W. W. Robertson, A. E. Martin, Frank L. Fuller, Lewis M. Bancroft, and M. F. Collins.

On motion of Mr. Holden, adjourned.

EXECUTIVE COMMITTEE.

The Executive Committee met at headquarters, Tremont Temple, at 12 M., Wednesday, December 9, 1903. Present: President Charles K. Walker and Messrs. V. C. Hastings, E. C. Brooks, H. G. Holden, L. M. Bancroft, Willard Kent, R. J. Thomas, and C. W. Sherman.

Five applications for membership were received, and it was voted to recommend the applicants to the Association for election.

An invitation to hold the next annual convention in Holyoke was received. It was voted that the President appoint a committee of three to consider and report upon the places for holding the next annual convention, and also the June meeting.

Voted, that the Editor be authorized to make arrangements for discontinuing the sending out of three hundred sample copies of each issue of the JOURNAL, at his discretion.

Adjourned.

WILLARD KENT, *Secretary.*

JANUARY 13, 1904.

The Executive Committee met at headquarters, at 11.30 A.M. Present: President Charles K. Walker and Messrs. H. G. Holden, J. C. Hammond, Jr., R. J. Thomas, L. M. Bancroft, C. W. Sherman, and Willard Kent. Five applications for admission to the Association (three as member and two as associate) were received, and it was voted to recommend the applicants for ballot.

Adjourned.

WILLARD KENT, *Secretary.*

FEBRUARY 10, 1904.

Present: President Brooks and Messrs. E. W. Kent, Willard Kent, H. G. Holden, V. C. Hastings, L. M. Bancroft, G. A. Stacy, C. W. Sherman, F. E. Merrill, J. E. Beals, and R. J. Thomas.

Eight applications for member and one for associate were considered, and it was voted to recommend the applicants to the Association for ballot.

The question of the necessity for additional room at headquarters was discussed.

The committee previously appointed to consider the place for the annual convention of 1904 reported in favor of Holyoke, Mass., and the Executive Committee voted that the convention be at Holyoke.

Treasurer Bancroft suggested that the Treasurer of the Association ought to give a bond. After discussion, it was voted that the President, Secretary, and Editor be a committee to purchase a suitable surety-company bond for the Treasurer, at the expense of the Association.

The question of election of honorary members was discussed, and it was voted that the President appoint a committee of three to consider the question and to report names for election to honorary membership if in their judgment it is desirable. The President appointed Messrs. Sherman, Willard Kent, and Holden on that committee.

Attention was called to Senate Bill No. 87, now before the Massachusetts Legislature, which would result in removing most if not all sanitary protection of water supplies. It was decided that the Association ought not to appear by a committee before the committees of the Legislature, but that attention of members should be called to the bill and such proper action taken as the meeting might decide.

Adjourned.

WILLARD KENT, *Secretary.*

OBITUARY.

ALPHONSE FTELEY, Civil Engineer, an honorary member of the New England Water Works Association, died June 11, 1903.

Mr. Fteley was born in Paris, France, April 10, 1837. He received his professional education at the Ecole Polytechnique in Paris, from which he was graduated in 1859. After six years of varied engineering work in France, he came to the United States in 1865. From 1866 to 1870 he was general assistant to William E. Worthen, on miscellaneous civil, hydraulic, and mechanical engineering work. In 1870 he opened an office in New York City for general engineering practice.

In May, 1873, Mr. Fteley was called to Boston to take charge, under Joseph P. Davis, City Engineer, of the construction of the Sudbury River Water Works. This work, with many additional investigations connected therewith, continued until 1880. During his connection with this work, the accurate gagings of the flow of the Sudbury River were begun, and at this time he also carried out, in connection with his assistant, Mr. Frederic P. Stearns, important experiments on the flow of water over weirs and through aqueducts and upon the accuracy of current meters.

From 1880 to 1884 Mr. Fteley was Chief Assistant City Engineer of Boston. In January, 1884, he accepted the position of Principal Assistant and Executive Engineer on the Croton Aqueduct, New York, under Mr. Benjamin S. Church, Chief Engineer. In 1886 Mr. Fteley became Consulting Engineer of this work. In 1888 he was appointed Chief Engineer of the Aqueduct Commission, and continued in this position until failing health made it necessary for him to resign at the end of 1899. While occupying this position, Mr. Fteley had charge of the design and construction of very important works, including the Jerome Park Reservoir and the New Croton Dam and other dams upon the Croton River and its branches.

After retiring from active practice, Mr. Fteley's failing health required him to avoid all physical exertion, but his mental powers remained undiminished and he attended to a limited amount of consulting work.

Mr. Fteley was a member of the Boston Society of Civil Engineers, and also the American Society of Civil Engineers, of which he was president in 1898. He was elected a member of the New England Water Works Association June 18, 1885, and an honorary member September 10, 1902.

Mr. George A. Ellis, Civil Engineer, who for nearly fourteen years was City Engineer of Springfield, Mass., died at his home in that city on December 27, after suffering for a period of eighteen months from valvular disease of the heart.

Mr. Ellis had of late years been acting as a consulting engineer, and had been engaged on many important works throughout the country. He was born in Ashland in 1843; was City Engineer of Springfield from 1874 to 1886; was appointed Chief Engineer of the Springfield, Athol & Northeastern R. R. in 1873, which position he held for a short time, as he did also that of Superintendent; acted as Chief Engineer in the construction of part of the Longmeadow & Springfield R. R.; has had charge of the installation of water systems at Racine, Wis.; Montgomery, Ala.; Sharon, Mass.; Marion, Ohio; and in other towns, and in recent years has been connected with the construction of electric railways.

Mr. Ellis was elected a member of the England Water Works Association on June 21, 1883, and was its third president, serving for the year 1884–85. His portrait was printed in the Journal of December, 1902 (Vol. 16, No. 4), where it faces page 280.